RISK ASSESSMENT OF HEAVY METAL ASSOCIATED WITH DERMAL EXPOSURE IN INCENSE WORKERS IN SMALL HOUSEHOLD FACTORIES AT ROI-ET PROVINCE, THAILAND

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การประเมินความเสี่ยงจากการสัมผัสโลหะหนักผ่านทางผิวหนังของคนงานผลิตธูปในครัวเรือน หมู่บ้านงูเหลือม จังหวัดร้อยเอ็ด ประเทศไทย

นางสาว พรรัตน์ แก้วเรือง

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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Thesis Title	RISK ASSESSMENT OF HEAVY METAL ASSOCIATED WITH DERMAL EXPOSURE IN INCENSE WORKERS IN SMALL HOUSEHOLD FACTORIES AT ROI-ET PROVINCE, THAILAND
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พรรัตน์ แก้วเรือง :
การประเมินความเสี่ยงของการสัมผัสโลหะหนักผ่านทางผิวหนังของคนงานผลิตธูปในครัวเรือน หมู่บ้านงูเหลือม จังหวัดร้อยเอ็ด ประเทศไทย (RISK ASSESSMENT OF HEAVY METAL ASSOCIATED WITH DERMAL EXPOSURE IN INCENSE WORKERS IN SMALL HOUSEHOLD FACTORIES AT ROI-ET PROVINCE, THAILAND)
อ.ที่ปรึกษาวิทยานิพนธ์ ผศ.ดร.วัฒน์สิทธิ์ ศิริวงศ์, 100 หน้า

หมู่บ้านงูเหลือมในจังหวัดร้อยเอ็ดเป็นหนึ่งในหมู่บ้านในภาคตะวันออกเฉียงเหนือของประเทศไทยที่มีการผลิตธูปจำนวนมากการรับสัมผัสสารโลหะหนักผ่านทางผิวหนังเป็นสิ่งที่น่าสนใจเพราะขั้นตอนการบรรจุธูปเป็นกระบวนการหลักที่เกี่ยวข้องกับการรับสัมผัสโลหะหนักหลายชนิด โดยเหตุผลหลักที่ต้องให้ความสำคัญเพราะการใช้สีคนงานผลิตธูปมีคุณภาพต่ำ การสุ่มตัวอย่าง 35 ครัวเรือนจากหมู่บ้านงูเหลือมนั้น จะต้องสุ่มคนงานบรรจุหีบห่อธูปครัวเรือนละ 1 คนเพื่อเก็บจำนวนโลหะหนักที่เหลืออยู่บนมือ ซึ่งพบสารโลหะหนักทั้ง 6 ชนิด คือแบเรียม แคดเมียม โครเมียม นิกเกิล แมงกานีส และตะกั่ว บนมือของคนงานผลิตธูป โดยมีร้อยละของ recovery ของโลหะหนักทั้ง 6 ชนิดบนผ้ากลอส อยู่ในช่วง 89.4 ถึง 102.6% ความเข้มข้นเฉลี่ย (±SD) ของ แบเรียม แคดเมียม โครเมียม นิกเกิล แมงกานีส และ ตะกั่ว ที่มือของคนงาน 11.03±2.31 1.13±0.23 2.77±0.83 7.06±1.92 8.20±2.22 และ 3.55±1.32 มก./กก. ตามลำดับ ค่าการรับสัมผัสทางผิวหนัง ของคนงานผู้หญิง คือ 1.48×10^{-7} 1.54×10^{-9} 3.68×10^{-8} 9.55×10^{-8} 1.12×10^{-7} และ 4.76×10^{-8} มก./กก.-วัน ค่า hazard quotient (HQ) ของ แบเรียม แคดเมียม โครเมียม นิกเกิล แมงกานีส และ ตะกั่วคือ 3.02×10^{-5} 1.28×10^{-4} 2.45×10^{-3} 1.59×10^{-4} 5.60×10^{-4} และ 1.13×10^{-4} ตามลำดับ และค่า hazard index (HI) ของทั้ง 6 โลหะหนักคือ 3.44×10^{-3} ค่าการรับสัมผัสทางผิวหนัง บนมือคนงานผลิตธูปชาย (n=5) ของ แบเรียม แคดเมียม โครเมียม นิกเกิล แมงกานีส และ ตะกั่ว 1.80×10^{-7} 1.72×10^{-9} 4.79×10^{-8} 1.11×10^{-7} 1.23×10^{-7} และ 5.83×10^{-8} มก./กก.-วัน ตามลำดับ ค่า HQ ของ แบเรียม แคดเมียม โครเมียม นิกเกิล แมงกานีส และตะกั่ว 3.67×10^{-5} 1.43×10^{-4} 3.19×10^{-3} 1.85×10^{-4} 6.14×10^{-4} และ 1.39×10^{-4} ตามลำดับ และค่า HI คือ 4.31×10^{-3} ดังนั้นทั้งค่า HQ สำหรับแต่ละสารโลหะหนัก และค่า HI ของทุกสารโลหะหนักมีค่าไม่เกิน 1 แสดงว่าในการศึกษานี้ไม่พบความเสี่ยงจากสารที่ไม่ก่อให้เกิดมะเร็งผ่านจากการสัมผัสทางผิวหนัง

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PORNRAT KAEWRUENG: RISK ASSESSMENT OF HEAVY METAL ASSOCIATED WITH DERMAL EXPOSURE IN INCENSE WORKERS IN SMALL HOUSEHOLD FACTORIES AT ROI-ET PROVINCE, THAILAND.,100 pp.

The Ngooleum village in Roi-et province is one of the largest producers of incense stick in the northeastern region of Thailand. An exposure of heavy metal through dermal contact is concerned because packaging is the main production process that involves of several heavy metals contact. Thirty-five small household factories were selected randomly to collect heavy metal residues on one packaging worker's hands of each factory. The average residue concentrations (±SD) of Ba, Cd, Cr, Mn, Ni, and Pb on worker's hands were 11.03±2.31 mg/kg, 1.13±0.23 mg/kg, 2.77±0.83 mg/kg, 7.06±1.92 mg/kg, 8.20±2.22 mg/kg, and 3.55±1.32 mg/kg, respectively. The dermal absorbed dose (DAD) of female workers (n=30) of Ba, Cd, Cr, Mn, Ni, and Pb were 1.48×10^{-7} mg/kg-day, 1.54×10^{-9} mg/kg-day, 3.68×10^{-8} mg/kg-day, 9.55×10^{-8} mg/kg-day, 1.12×10^{-7} mg/kg-day, and 4.76×10^{-8} mg/kg-day, respectively. The risk in term of hazard quotient (HQ) of Ba, Cd, Cr, Mn, Ni, and Pb were 3.02×10^{-5}, 1.28×10^{-4}, 2.45×10^{-3}, 1.59×10^{-4}, 5.60×10^{-4}, and 1.13×10^{-4}, respectively and hazard index (HI) for six heavy metals was 3.44×10^{-3}. Another dermal absorbed dose (DAD) from male workers (n=5) of Ba, Cd, Cr, Mn, Ni, and Pb on worker's hands were 1.80×10^{-7} mg/kg-day, 1.72×10^{-9} mg/kg-day, 4.79×10^{-8} mg/kg-day, 1.11×10^{-7} mg/kg-day, 1.23×10^{-7} mg/kg-day, and 5.83×10^{-8} mg/kg-day, respectively. The hazard quotient (HQ) of Ba, Cd, Cr, Mn, Ni, and Pb were 3.67×10^{-5}, 1.43×10^{-4}, 3.19×10^{-3} , 1.85×10^{-4}, 6.14×10^{-4}, and 1.39×10^{-4}, respectively and the hazard index (HI) was 4.31×10^{-3}. In conclusion, Both the HQ values for single heavy metal and HI value for six heavy metals were greatly below one indicated incense workers may not be greatly risk from these heavy metals via dermal route.

Field of Study : Environmental Management Student's Signature : ....

Academic Year : 2012 Advisor's Signature: ....

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ABBREVIATIONS

ABS	Absorption factor
AF	Adherence factor of soil to skin
AT	Averaging time for non carcinogen
Ba	Barium
BW	Body weight
C	Concentration
Cd	Cadmium
CF	Conversion factor
Cr	Chromium
DAD	Dermal absorb dose
DAevent	Absorbed dose per event
ED	Exposure duration
EF	Exposure frequency
EV	Event frequency
H	Height
HI	Hazard Index
HQ	Hazard quotient
Mn	Manganese
Ni	Nickel
Pb	Lead
RfD	Reference dose
US EPA	United State Environmental Protection Agency

CHAPTER I
INTRODUCTION

1.1 Background

Incense sticks have been widely used, especially in Asian countries which respect to Buddhism, Taoism and Shinto religions (Lin,*et. al*, 2008). The reasons of using incense sticks in many holy ceremonies of each religion are the belief that it is a connection to god and it sends souls of the deceased. Thailand is one of Asian countries that have adopted the belief from India. Incense sticks are produced and used in several provinces in Thailand such as Ayutthaya, Chiang Mai, Chai Nat, Singburi, Pathumthani, Uthaithani and Roi Et. In this case study, the chosen province is Roi Et since it is one of the largest production site of incense stick in the northeastern region of Thailand (figure 1.1). Roi Et is composed of many small household factories. However, the research area of this study focuses on Ngooleum village, Dong Dang Sub district, and Chaturaphak Phiman district. The area consists of 12 villages. Moo 12 is selected as it earns the best income from incense production. The main occupation for a living in the village is incense work; other occupations are farmer, shallot growing, merchant, and employee for supporting income. Several types of incense stick are produced in the area but the incense stick that Thai people call " Toop-sad" is the most popular product with the length about 20 centimeters. The top of bundle is mold with saw dust and the other components, while the bottom is always colored by dipping in red and pink colors. Incense stick process is separated into 6 steps, which are (1) bamboo preparation, (2) incense powder mixing, (3) incense molding, (4) color dipping and dyeing, (5) perfume spraying, and (6) packing. From all of incense making steps, the packing step lead to workers to the highest risk to contact dyeing color because they pack incense with nothing wraps their hands. The dyeing colors in incense making process are synthetic color powder that is composed of heavy metals such as lead, cadmium, and zinc. Those metal atoms can form new structures with organic molecules and the fluxes of metal electrons create intense colors (Erich, 2004). Heavy metals can cause chronic affects. The main effects are cancers, kidney damage, nervous system damage (Lars, 2003), skin changes, impaired cognitive, lethargy, insomnia, and emotional instability. Besides, the signs can occur in acute effect as headaches, skin rash, cramp, vomit, sweat and difficulty breathing (Rook*et al*, 2004). Dermal exposure is the main route that the dyeing colors contact human body. Thus hand wipe method is employed to collect samples of heavy metals on workers' hands. Thirty-five small household factories are selected from 100 small household factories in the village for sample collection (Jaipieam, 2008). Each small household factory has the whole process of incense production, but the workers who responsible to incense packing step are chosen randomly to collect samples by gauze wiping technique. Hand wipe samples were collected for three times per a small household factory. First is in the morning before the workers work incense process, second is before they have lunch, and third is after the workers wash their hands before having lunch. Only ten of thirty-five small household factories are collected samples for four times. Furthermore, the samples from the workers who use gloves are collected in the afternoon after the workers finish work. Moreover, dissolved dye and incense stick from the small household factories area lso collected to estimate heavy metal concentrations and to consider the mean difference between dissolved dye, dyeing color on incense stick, and dyeing color on workers' hands. All samples are digested using microwave digester. The digested samples are measured for concentrations of six heavy metals that were barium (Ba), cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni), and lead (Pb) by inductively coupled plasma optical emission spectrometry (ICP-OES).

1.2 Research question

1.2.1 Are incense stick worker in Ngooleum village at risk from heavy metal via dermal exposure?

1.3 Hypothesis

1.3.1 The health risk of incense stick workers in Ngooleum village is increasing by dermal exposure among incense production.

1.4 Objectives of the study

1.4.1 To estimate heavy metal concentrations in dissolved dye on incense stick and workers' hands.

1.4.2 To investigate dermal exposure of heavy metal for the worker in household incense production.

1.4.3 To assess the potential risk of heavy metal related to dermal exposure of incense workers.

1.5Scopes of the study

1.5.1 Estimate heavy metal concentrations in dissolved dye at thirty-five small household factories.

1.5.2 Estimate heavy metal concentrations on incense sticks, which are dried after coat with dyeing color.

1.5.3 Estimate heavy metal concentrations in hand wipe samples, which are wiped on packing worker's hands.

1.6 Research outcomes

1.6.1 Heavy metal concentration of dissolved dye, incense stick and hand wipe samples in Ngooleum village will be analyzed.

1.6.2 The human health risk of incense stick workers who risk contaminating heavy metal in dyeing color will be assessed.

1.6.3 The information can be utilized for risk management and reach to avoid heavy metal from dyeing color in the incense stick process.

OPERATIONAL DEFINITIONS

Analysis refers to the use of inductively coupled plasma optical emission spectrometry (ICP-OES) to analyze the concentrations of six heavy metals and the unit of analysis is ppm (mg/kg).

Digestion refers to the microwave digestion that method use to digest dissolved dye, incense stick, and hand wipe samples.

Dyeing color refers to dye is used for dipping a bundle of incense.

Exposure refers to dermal exposure is the route that workers contact dye on incense bundle via hand skin.

Heavy metals refer to six heavy metals as barium (Ba), cadmium (Cd), chromium (Cr), manganese (Mn), nikle (Ni), and lead (Pb), which cause non-carcinogenic effect.

Hand wiping method refers to the method that use gauze pad wipes dyeing color on worker's hands.

Incense worker refers to workers who pack incense in the incense making process.

Incense stick refers to a bundle of Toop-sad or small incense that covers with red or pink colors.

Risk refers to the opportunity to contact with dyeing color on incense bundles when worker pack incense.

Risk assessment refers to the risk assessment from dermal exposure of incense worker.

CHAPTER II

THEORY BACKGROUND AND LITERATURE REVIEWS

2.1 Incense stick

2.1.1 History of incense stick

Incense began around thousands of years; it has been used expanded in the ancient civilizations of Mesopotamia, Phoenicia, Arabia, Egypt, India, Greece and Rome. In the early always used ground herbs, flowers, berries, spices and fragrant woods such as cedar, pine and cypress to make incense. Because of these natural material have smell when they burning, professional believe the burning was the beginning of incense. In religious ceremonies used incense for therapeutically objectives and recover rituals. For the historical of incense in India, it is called "agarbatti" , so has unique fragrance and it used in medicine and aroma to healing. When Hinduism and Buddhism began, incense was use in the holy religion ceremonies. Moreover, the Buddhism monks though incense making process to Chinese monks in Tang dynasty (607-618) (Falcon band incense sticks). After that Chinese monks who created from the original incense to incense sticks developed it during the Ming dynasty. They made the herbs, flowers, berries, spices and plants in natural were powder to easy for mixing with natural glue and then molded the mixed ingredient around a bamboo stick (Asian art mall). In late 1800 century, Japanese completed the cone incense and presented the new form to the World Fair in Chicago, America. It was popular in Japan because whole school gave it to the art. When burning incense stick, cone incense or other shape, the unique smell from each part of nature or aromatic fragrance made people remember and familiar these and now incense is used almost in routine of Asian people everyday as well as temples, houses, and shrines (Lucky turtle incense, 2012).

2.1.2 Incense stick making process

The incense making process can be divided into 6 steps as bamboo preparing, incense powder mixing, incense molding, color dipping and drying, perfume spraying, incense packing. Five main raw materials are bamboo, glutinous incense powder, sawdust, dyeing color, and perfume oil and powder are used in incense making process. First, the top of bamboo sticks are dipped in water as the same length then mix with glutinous incense powder, so it makes the sticks are sticky especially in wet part. Mixing glutinous incense powder with saw dust for coating the wet part of incense sticks three to five times, so each time must break the process by dipping water. The last coating is used sandal powder, which make incenses are white and mix with alapa, which is sticky substance, then dry incense sticks on the out side. The dried incense sticks are dipped in dissolved dye as pink or red colors. Pink color use pink powder mix with water, whereas red color use pink powder and yellow color mix together with 2:1 ratio and then dry incense stick on the outside. Next, spray incense sticks with perfume or dip in fragrance. The last step is incense packing step and wrapping with transparent plastic.

1. Shaped bamboo for incense stick making

Figure 2.1 Bamboo stick for incense stick making process

2. Glutinous incense powder and saw dust mixing together for coating the upper part of incense stick.

Figure 2.2 Glutinous incense powder and saw dust

3. Coating incense stick by rolling and shaking with glutinous incense powder and saw dust mixed then drying on the outside.

Figure 2.3 Molding and drying the upper part of incense stick

4. Dipping the bottom part of incense stick with dyeing color and drying.

Figure 2.4 Dissolved dye for dipping the lower part of incense stick

5. After perfume spraying, incense sticks are packed in plastic package.

Figure 2.5 Packing incense worker

2.2 Industrial dye

Industrial dye is the source that involves heavy metal because paint or dyeing color for textiles, house, or furniture always add heavy metal. In the past, lead popular for adding in paint industrial. It contain lead more than 0.06% lead by weight and use in interior and exterior residential surface, moreover, it always use for toys and furniture. However, lead in paint is still adding in the component for industrial dye (Saleh, 1995) Dyeing color is a colored substance in liquid or powder forms that can adsorb light and on the surface object and spared inner the object structure, so the object appear a colored object. Dyeing color can be divided into 2 types as natural dye and synthetic dye. Natural dyes are produced from parts of plant as root, bark, leave, berry and wood depend on interested color. The types of plants source are different from each location locally. In 1856, Perkin discovered synthetic dyes and produced many type of dyes to specific for using as acid dyes, basic dyes, direct dyeing, mordant dyes, vat dyes, reactive dyes, disperse dyes, azotic dyeing, and sulfur dyes (Hunger, 2003). Textile colorant contain chromium in component, so chromium atom can form with an organic molecule as a new structure called a metal-complex dye. The reason for using metal in textile colorant is the flux of metal electrons makes intense color. Although dye molecule is broken down, Chromium can stay chromium atom. It is released to environment and cause adverse effect or symptoms when contact to human (Erich, 2004). Moreover, reactive dye and dyeing color are used in textile industry to make color or printing in the products. The dyes contain high heavy metal concentration but in textile products may be found at low concentration and can cause health effect to human (Tuzen, 2008).

2.3 Heavy metals

Generally, 35 metals are concerned in daily life but 23 elements are heavy metals (Glanze, 1996). Heavy metals are natural elements which have an atomic number of 200 or over (Dianne, 1999) as antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc. Actually, a small amount of heavy metal are essential for health life, they are called trace elements such as iron, copper, manganese, and zinc. These elements are always found nationally in food products, fruits and vegetables (International Occupational Safety and Heath Information Centre, 1999). Example for more benefit of heavy metal as in demonstrative medical applications use gallium during radiological procedures by direct injection, and use lead in x-ray process as a radiation shield of x-ray equipment (Roberts, 1999). Moreover, heavy metals are used commonly in industrial applications such pesticides, batteries, alloys, electroplated metal parts, textile dyes, and steel industrial (International Occupational Safety and Heath Information Centre, 1999). Human can expose to heavy metal in pass through inhalation, ingestion or contact with the skin, for example; humans can expose from many ways in agriculture, manufacturing, pharmaceutical, and industry process. Children who always contact soil and like to eat or keep object in the mouth can expose heavy metal by hand-to mouth (dirt or paint chips) (Dupler, 2001). The Figure2.6 shows exposure pathway of inhalation, ingestion and dermal contact, so all of exposure can make chemical substance enter to body but the adverse effect depend on many parameters such as dose, chemical type, time, gender, and age. A large amount of heavy metal can cause harmful effects depend on types of heavy metal. Heavy metals can accumulate in human tissue and occur toxic when they cannot be metabolized by human metabolism. Toxicity of heavy metal in acute effect that signs present in rapid time such as cramping, nausea, vomiting pain, sweating, headaches, difficulty breathing, impaired cognitive, motor and language skills changing, mania, and convulsions (Ferner, 2001). The results from chronic exposure can damage mental and nervous system as slowly in physical improvement, Alzheimer's disease, Parkinson's disease, muscular dystrophy, and complicated sclerosis (International Occupational Safety and Heath Information Centre, 1999). In the case study, serveral heavy metals are in dissolved dye but barium, cadmium, chromium, manganese, nickel, and lead are concerned because of their harmful effects and Table 2.1 shown the physical properties of each element.

Table 2.1 The physical properties of elements

Information	Elements					
	Ba	Cd	Cr	Mn	Ni	Pb
Atomic number	56	48	24	25	28	82
Phase	Solid	Solid	Solid	Solid	Solid	Solid
Melting point (°C)	727	321.07	1,907	1,246	1,455	327.46
Boiling point (°C)	1,897	767	2,671	2,061	2,913	1,749

2.3.1 Barium

The quantitative information to exposure barium via dermal contact is little and has a limited in some case. Barium can cause corrosive when the skin contacts with barium hydroxide or other barium compounds that have potentially corrosive (ATSDR: Barium and barium compound, 2005).

2.3.2 Cadmium

Cadmium can be absorbed greatly 0.5% through the skin so cadmium exposure is concerned some cases that expose cadmium at high concentration via the skin for longtime or many hours (Corrosion doctor, 2012). Even though dermal absorption of cadmium is not important like via inhalation and ingestion, some cadmium compound can cause irritate to the skin (Sittig, 1985).

Chronic effect in long term exposure to cadmium directly cause the kidney damage (WHO, 1992), but there is not know the information and health effect of skin contact with cadmium in humans or animals (ATSDR, 1999).

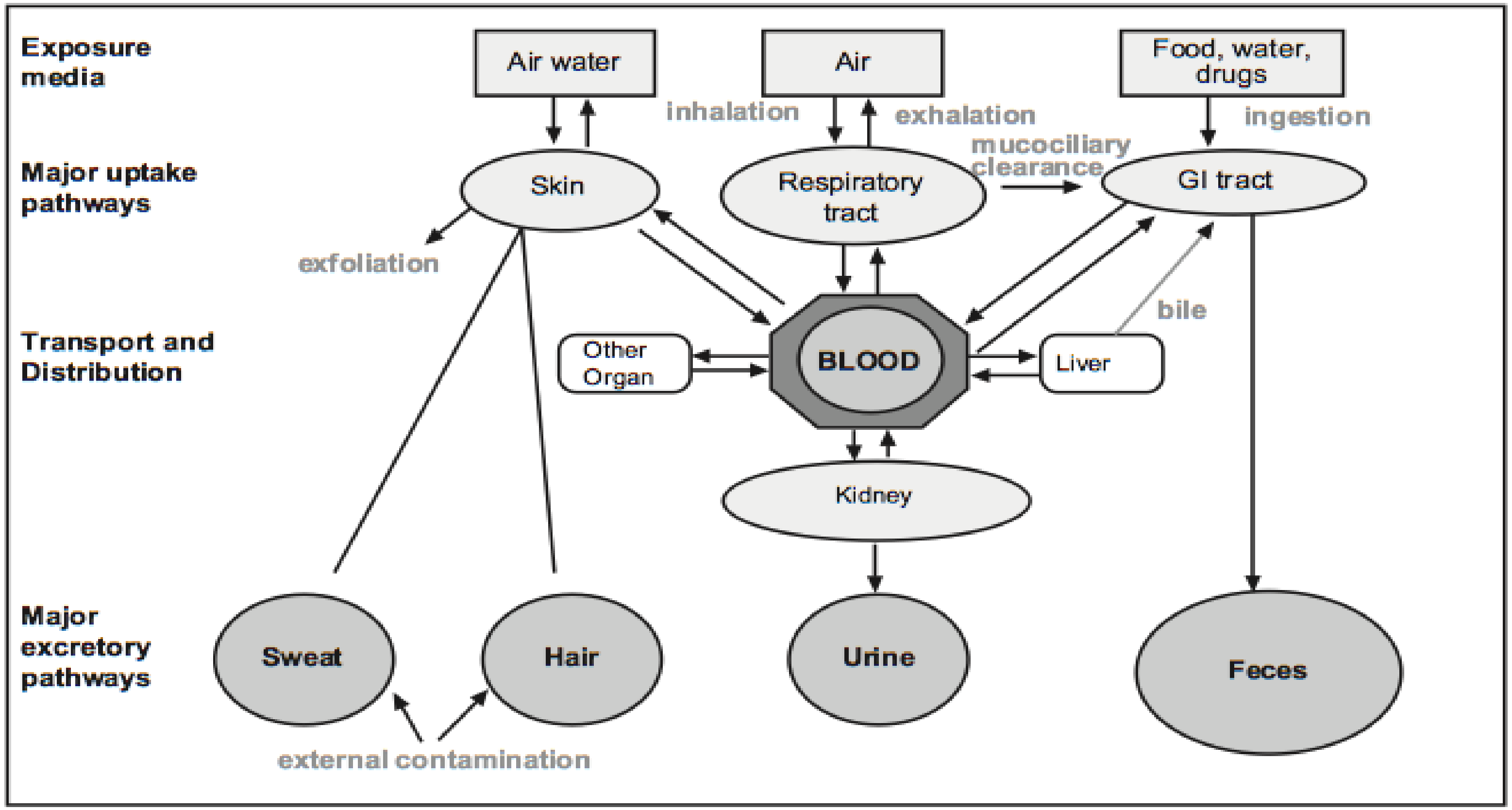


Figure 2.6 Exposure and metabolic pathways for elements (Clarkson et al., 1998)

2.3.3 Chromium

Many chromium exposure studies in vivo of human and animal toxicokinetic reported that chromium could absorb via the skin but cannot estimate and identify the percentage of chromium absorption (NIOSH, 2010). Chromium has two main oxidation states are trivalent chromium cation (Cr^{3+}) and chromate anion (Cr^{6-}) (ATSDR, 2000). The study of chromium dermal absorption is reported in vitro gas diffusion cell that study full-thickness abdomen of human skin (Gammelgaad et al, 1992). The research was studied the exposure of chromium (III) chloride ($CrCl_3$), chromium (III) nitrate [$Cr(NO_3)_3$], and potassium dichromate ($K_2Cr_2O_7$) to the skin barrier. The study test was 190 hours and the results found that only $K_2Cr_2O_7$ can pass through the skin. In the skin layers, the chromium concentrations of $K_2Cr_2O_7$ more than $CrCl_3$ and $Cr(NO_3)_3$ were 10 times and 15-30 times, respectively. As a result, the Cr (VI) can diffuse pass through the skin more than Cr (III) (Elemental speciation in human health risk assessment: Environmental health criteria 234).

Acute toxicity of Cr (VI) and Cr (III) are different, so the toxic of hexavalent chromium is higher than trivalent chromium. The effects of chromium present mostly via inhalation and ingestion, so chromium can damage respiratory tract pass through inhalation and irritates mucosal tissue, damage cardiac, intestine, hepatic and kidney and potentially death pass through oral. For dermal contact, chromium cause allergy to dermal skin in acute effect. Moreover, chronic effect of chromium can deeply permeability through skin and presents more effect than acute effect (Assem and Zhu, 2007). The main target organ that can absorb chromate is kidney.

2.3.4 Manganese

Manganese is one of essential nutrient but can cause neurotoxicity to human through inhalation or ingestion (WHO, 1981; WHO 1999a). Dermal absorption of manganese is reported to exposure gasoline additive 2-methylcyclopentadienyl manganese tricarbonyl (MMT) via the skin when contact with concentrated solutions (ACGIH, 1991).

2.3.5 Nickel

For dermal absorption, the study of measurement in depth concentration profiles of a number of different nickel salts in the stratum corneum of human volunteers found the nickel salts of acetate, nitrate, sulfate, and chloride can cause penetration as a function of the counterion from high to low respectively (Hostynek et al., 2001). Another case studied human skin under occlusion and penetration of Ni^{2+} ion from $NiCl_2$ via the skin. The results found that Ni^{2+} from $NiCl_2$ can occlude and penetrate 0.23% when applied dose after 144 hours and 40–50 times quicker than from $NiSO_4$. If without occlusion, $NiCl_2$ can penetrate reduce more than 90% and not found absorption when used $NiSO_4$. However, these results are in agreement that under occlusion using $NiCl_2$ rather than $NiSO_4$ were probably to produce a positive reaction in nickel-sensitive patients (Fullerton et al., 1986).

2.3.6 Lead

The absorption of inorganic lead compounds through the skin is not important as exposure via oral and inhalation (ATSDR, 2005b). For dermal absorption via the skin, the skin is low penetrated when expose to lead (II) oxide (PbO) and lead (II) acetate, but organolead compounds can cause much more effect Bress & Bidanset, 1991).

Lead compounds as well as inorganic and organic lead are neurotoxicity so affects the central nervous system, but the effects of both compounds are different (Feldman, 1999). Moreover, many compounds such as trimethyl and triethyl lead and trialkyl metabolites of tetramethyl and tetraethyl lead are neurotoxicity (Tilson et al., 1982; Hong et al., 1983; Walsh et al., 1986; Verity et al., 1990; Yagminas et al., 1992). Signs and symptoms of lead exposure are irritation, insomnia, dream disturbance, illusion, anorexia, nausea, vomit, tremulousness, and ataxia (WHO, 1997).

2.4 Qualitative risk assessment

Qualitative risk assessment is rapid risk assessment to estimate the risk in the case study. A risk matrix is used to weigh the evidence that is interested. The risk matrix presents the various levels of risk as considering the harm exposure of evidence. Qualitative is described as amount or number that can apply with risk assessment. Qualitative risk assessment is estimated the risk from frequency and consequence in axial. The risk from scenario can be estimated in digit and can be made the objective by using numerical scales (Thomas, 1985). Figure 2.7 shown qualitative risk matrix that adopt from qualitative risk assessment technique (Thomas, 1985) to estimate the risk in incense small household factory. The vertical axis of the risk matrix is time working frequency that weighs a score relating with working time per week (hr/week) in Table 2.2 as well as horizontal axis in Table 2.3 shown consequence symptoms that weigh the scores depending on the level of symptoms when expose heavy metal.

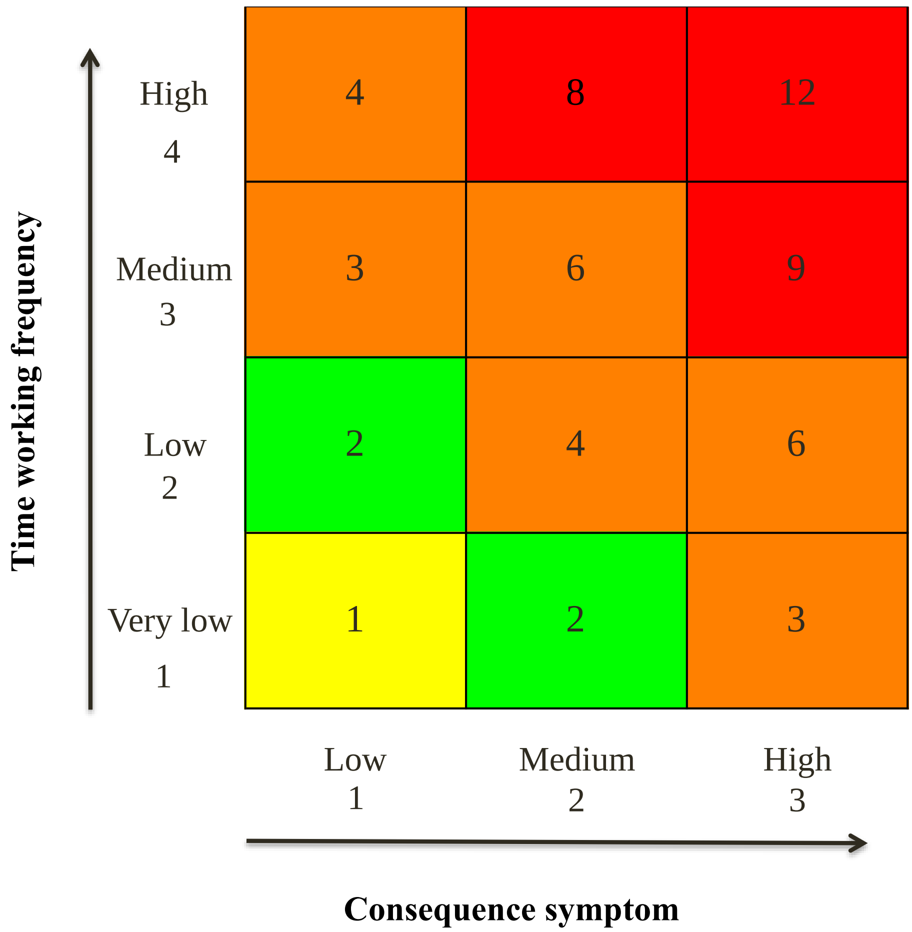


Figure 2.7 Qualitative risk matrix (Thomas, 1985)

Table 2.2 The probability time working frequency that is defined as the working duration time of incense worker (hr/week)

Score	Consequence rating	Duration time (hr/week)
1	Very low	7-14
2	Low	14-28
3	Medium	28-42
4	High	Above 42

Source: Rook et al, 2004

Table 2.3 The consequence symptom of dermal contact with heavy metal

Score	Consequence rating	Definition
1	Low	Worker has nothing in symptom
2	Medium	Worker has skin rash
3	High	Worker has skin change

Source: Rook et al, 2004

Table 2.4 The probability of health risk and definition

Score	Consequence rating	Colors	Definition
1	Very low		Workers in this case are the lowest priority in the risk management case. The effect is not effect health and day life but they should to know the information about heavy metal.
2	Low		Workers in this case are the next lowest priority in the risk management case. The effect may be risk to workers and they should to know the information about heavy metal.
3-6	Medium		Workers in this case are the medium priority in the risk management case. The effect is medium, so they should to know the information about heavy metal and should be concerned during planning and

Score	Consequence rating	Colors	Definition
			risk assessment.
8-12	High		Workers in this case are the highest priority in the risk management case. The effect is the highest, so they should to know the information about heavy metal and they should be concerned mainly during planning and risk assessment.

Source: Suwansan, 2012

2.5 Environmental health Risk assessment

2.5.1 Risk assessment steps

Risk assessment field has prevalent since 1970 (Paustenbach, 2002) that is conceptual framework that estimate environment and negative health effect in human who risk in chemical exposure (USEPA, 2010). The U.S. Environmental Protection Agency (USEPA) guidance 4 basic steps to estimation risk: hazard identification, dose-response assessment, exposure assessment, and risk characterization as shown in Figure 2.8 (Cirone and Duncan, 2000). Figure 2.8 shown the four fundamental steps in the risk assessment process.

Hazard identification	characterization of innate adverse toxic effects of agents
Dose-response assessment	characterization of the relation between doses and incidences of adverse effects in exposed populations
Exposure assessment	measurement or estimation of the intensity, frequency, and duration of human exposures to agents
Risk characterization	estimation of the incidence of health effects under the various conditions of human exposure

Figure 2.8 Four fundamental steps in the risk assessment process as defined by the NAS (NAS, 2007)

2.5.1.1 Hazard identification

Hazard identification is the first step that resolve whether exposure from agent which can cause specific harmful effect to human health. Moreover, this step distinguishes factors that support the identification and weight the evidence to identify the relationship between adverse effects and the chemical agent. Two keys components, which help the step identify the adverse effect from agent, are “ toxicokinetics ” and “ toxicodynamics ”. Toxicokinetics interested in the ways of each chemical agent enter to body by three main routes as inhalation, ingestion, and absorption. Moreover, toxicokonetics involve metabolism and elimination of chemical agents. On the other hand, toxicodynamics concerns the effects and metabolisms from each chemical agent to human body (USEPA, 2010).

2.5.1.2 Dose response assessment

This step explains the relationship between adverse health effects and the amount of agent, so these are related together, for example; if chemical agent dose increase, the human response increase too. The dose response relationship bases on the kind of chemical agents, responses, and analytic subject.

Some chemical agents are human carcinogens; so the carcinogenic slope factor (SF) is used to assess the risk of human carcinogen depend on chemical agent exposure. Slope factor is toxicity data that used in risk assessment to estimate relationship between dose and response of human carcinogen by estimation an upper bound lifetime. The weight of evidence is data, which escort with slope factor, to signify the strength of evidence to human carcinogen value. Slope factor represents an upper bound only average risk or random risk in individual selection but not the high risk in individual or group. The terms of SF are risk per unit of chemical concentration (mg) per unit body weight (kg) per unit time (day) or $(mg/kg/day)^{-1}$(US EPA, 2005).

In contrast, non-carcinogens are evaluated the effects by using an exposure or dose called “ Reference dose (RfD)”. RfD is value that specific for an exposure depended on bioavailability consideration or other parameters to intimate specific dose-response relationship (USEPA, 2010). Chronic RfD is value for protection in long term exposure as 7 years of a lifetime, but sub-chronic RfD is used to estimate in short term exposure of chemical agent as 2 weeks to 7 years (USEPA, 1989). Table 2.5 shown dermal Reference dose (RfD_d) in unit mg/kg-day and dermal absorption fraction (ABS_d) of elements.

Table 2.5 Dermal Reference dose (RfD_d) and dermal absorption fraction (ABS_d) of elements.

Elements	RfD dermal (mg/kg-day)	Reference	Dermal absorption fraction (ABS_d)	Reference
Ba	4.9×10^{-3}	Robson et al.	0.01	EPA, 1995
Cd	1.2×10^{-5}	Robson et al.	0.001	EPA, 1992
Cr (VI)	1.5×10^{-5}	IRIS	0.01	EPA, 1995
Mn	6.0×10^{-4}	IRIS	0.01	EPA, 1995
Ni	2.0×10^{-4}	IRIS	0.01	EPA, 1995
Pb	4.2×10^{-4}	Siyue et al, 2010	0.01	EPA, 1995

2.5.1.3 Exposure assessment

Exposure is defined as the connections between agents and the visible part of human that are dermal, oral, inhalation routes. Exposure assessment is the step that can be measured directly and indirectly, but in generally always measure by concentration in environment indirectly and attention values of fate and transport of chemical agents, and human intake over time.

Dermal exposure is the route that contact by skin. The skin is a barrier between the human inner body and outside environment, so chemical substance can absorb through the dead upper skin parts and then into the tissue and blood vessels in the lower skin layers (Erich, 2004).

For dermal exposure of risk assessment based on dose response relationships, the dermal absorb dose (DAD) equation is used to calculate dose of dermal exposure per day so the descriptions and units of each parameter are shown in Table 2.6. The DAD equation through dermal route is calculated by general equation following (USEPA, 2004):

$$DAD = \frac{(DAevent \times EV \times ED \times EF \times SA)}{(BW \times AT)} \quad (2.1)$$

$$DAevent = (C \times AF \times ABS_d \times CF) \quad (2.2)$$

$$SA = a_0 W^{a2} H^{a1} \quad (2.3)$$

Table 2.6 Input parameters to characterize the ADD value

Parameters	Description	Unit
SA	Surface area	cm^2
DAevent	Absorbed dose per event	mg/ cm^2-event
EV	Event frequency	event/day
ED	Exposure duration	years
EF	Exposure frequency	day/year
BW	Body weight	kg
AT	Averaging time for non carcinogen	days
Cs	Heavy metal concentration on both hands	mg/kg
CF	Conversion factor	kg/mg
AF*	Adherence factor of soil to skin	(mg/ cm^2- event)
ABS	Dermal absorption fraction	-
H	Height	cm
W	Weight	kg
a_0**	Default values	-
a_1**	Default values	−
a_2**	Default values	−

* AF is default value (US EPA, 2004)

** a_0, a_1, and a_2 are default values (US EPA, 1997)

2.5.1.4 Risk characterization

Risk characterization is the final step of risk assessment to conclude and integrate all information from hazard identification, dose response assessment, and exposure assessment. The integrated information can distinguish about the risk and predict the harmful effects from exposure. The toxicity results and exposure assessment are combined to achieve the quantitative estimation of cancer risk and hazard indices. Carcinogenic risk can be calculated by a linear equation 2.4 as follow:

$$\text{Cancer risk} = \text{DAD (mg/kg/day)} \times \text{SF (mg/kg/day)}^{-1} \quad (2.4)$$

If the result of cancer risk is less than 10^{-6}, the risk is in acceptable level.

For non-carcinogen is considered in exposure or average daily dose (ADD) with relating reference dose (RfD) of hazardous substance. Non-carcinogen can be calculated the effect as hazard quotient (HQ) by the relationship:

$$\text{Hazard Quotient (HQ)} = \frac{\text{Exposure or DAD}}{RfD_d} \quad (2.5)$$

Exposure = chemical exposure level (mg/kg/day)

RfD_d = reference dose (mg/kg/day)

Where:

$HQ \geq 1$ adverse non-carcinogenic effect concern

$HQ < 1$ acceptable level (not concern)

Hazard Index (HI) is the summation of HQ, if the HQ result has many routes and substances.

$$\text{Hazard Index (HI)} = \sum HQ \quad (2.6)$$

2.5.2 Reasonable maximum exposure (RME)

The reasonable maximum exposure (RME) always use in some case of risk assessment. The case is defined as the RME or upper bound because it is over exposure (approximately the 95^{th} percentile). The RME is the worst-case scenario that evaluates exposures that higher than average, nevertheless the exposures still within a practical range. The upper confidence at 95^{th} percentile is used to evaluate RME because the situation involves the uncertainty of concentration value. Exposure time and exposure frequency are used in term of 95^{th} percentile to calculate the exposure results in reasonable maximum exposure case, if statistical data are available (USEPA, 1989 and Siriwong, 2009). The average and upper bound value should be combined together for estimate the exposure and the results stand for the exact RME for the case (USEPA, 2002).

2.6 Related research articles

Duggan (1985) studied lead on children's hands and the lead in dust in playground from London school. The lead on hands was collected by hand wiping method, which used different four brands to clean on children's hands. Wiping about 10 seconds per hand and collected in plastic bag, then digested with wet acid digestion method of 15 ml mixed nitric acid and perchloric acid in ratio 4:1, and the last analysis the lead content by flame atomic absorption spectrophotometry. The children who selected to wipe must collected dust samples from playground school during lunch break by sweeping each area around 10 m^2. The samples were sieved pass through 500 µm sieved instrument, then digested with hydrochloric and nitric acid and used atomic absorption spectrophotometry to analyze the lead content. The results of wipe samples fond that the first wipe can removed about 60% lead on hands and the most size of lead on hands were less than 10 µm. Nevertheless, the particle size of dust samples always found less than 500 µm or 500 µm, so it not correlate between the quantity of lead on hand and the concentration of lead dust because some old school which selected repainted the playground.

David et al. (1999) studied on the four methods to determine the exposure of children in the case study of lead contaminated household dust. The four methods were wipe method, minivacuum (MVM), high-volume small surface sampler (HVS3), and the Nilfisk GS80 (GS80). The collection efficiency can be considered and calculated by the coefficient of variation (CV), and the results showed that HVS3 is the most efficiency as 0.01-0.06 (less than 1), GS80, wipe, and MVM respectively. Although wipe method is not the best method, it proper in public health exposure and risk assessment so it can be used many surfaces and especially on carpeted surface. Another one reason is cost of HVS3 so expensive, it not appropriate for normal case.

Elenora et al. (2002) studied on the Warynski smelter site that is renounced industrial area in Upper Silesia, Poland. The area was covered with hazardous material as cadmium, copper, iron, manganese, lead, and zinc, so that need to be in human health risk assessment to evaluate the potential risk to human. The case study can be divided into two scenarios as industrial and recreational scenarios. All of heavy metal that contaminated in the area, cadmium and lead were concern for industrial workers and recreational users. The results show that the cadmium and lead concentrations should be reduced to 1.17×10^3 mg/kg for cadmium, and 1.62×10^3 mg/kg for lead (industrial scenario). In recreational scenario, it could not calculate the lead concentrations because the method for lead assessment not had for this case, but the cadmium concentration should be reduced to 1.18×10^3 mg/kg.

Hye et al. (2008) studied in Songcheon Au-Ag mine in Korea on three topics; contamination levels and dispersion patterns of Arsenic, estimation the bioaccessible fraction of metals in soil and crop plant, and evaluation the health risk that effects on the area. ICP-AES and ICP-MS were used to estimate metals concentrations in tailing, soil, crop plant, groundwater, and stream water samples, except mercury was estimated the concentrations by cold vapor AAS. The results of the study found that; (1) the metal contamination in the mine were 143,813 mg As/kg, 20 mg Cd/kg, 749 mg Cu/ kg, 50,803 mg Pb/kg, 7,541 mg Zn/kg and 1.01 mg Hg/kg, and those in farmland soil were 626 mg As/kg, 1.4 mg Cd/kg, 673 mg Cu/kg, 2 mg Pb/kg, 399 mg Zn/kg and 4.90 mg Hg/kg; (2) The soil of crop plants were full of metal especially As was 33 mg/kg in root of green onion; (3) The concentration level of As, Cd, and Zn in drinking water over than the standard permission; (4) The bioaccessible fraction value in stomach was 3% As, 40% Cd, 15% Cu, 31% Pb and 21% Zn. For in simulated small intestine was 12% As, 2.2% Cd, 5.6% Cu, 0.5% Pb and 1.2% Zn; (5) The toxic risk (HI) value of heavy metal in the mine was 16. For As, the HQ was 15 and carcinogenic risk was 2.7×10^{-3}.

Hung et al. (2010) studied heavy metals contaminated in soil and groundwater so more than 600 sites in Taiwan that contaminated with heavy metals. This study used heavy metal concentration in the topsoil to calculate the risk, so the average concentrations of Cr, Cu, Ni and Zn were 83 mg/kg, 90 mg/kg, 219 mg/kg, and 346 mg/kg, respectively. The maximum concentrations of Cr, Cu, Ni and Zn were 207 mg/kg, 122 mg/kg, 412 mg/kg, 662 mg/kg, respectively. In this case studied all three routes via dermal contact, ingestion, and inhalation and hazard quotient (HQ) of each heavy metal came from the summation of three routes of exposure then divided by reference dose (RfD). The average and maximum HQ values of Zn, Cr, Cu, and Ni were 1.0×10^{-3} and 2.0×10^{-3}, 2.5×10^{-2} and 6.2×10^{-2}, 3.0×10^{-3} and 4.1×10^{-3}, and 9.8×10^{-3} and 1.9×10^{-2}, respectively. For carcinogenic risk, this study calculated only inhalation route of heavy metals that had slope factor as Cr and Ni. The carcinogenic risk at the average and maximum of Cr and Ni were 7.0×10^{-7} and 1.8×10^{-6} and 3.7×10^{-8} and 7.0×10^{-8}, respectively. In conclusion, this study was no non-carcinogenic and carcinogenic risks because the risk below one and 10^{-6}, respectively.

Singh, et al. (2010) studied heavy metal contaminated in vegetables at Varanasi, India. The source of heavy metals from wastewater irrigation, so this study quantified Cd, Cu, Pb, Zn, Ni, and Cr in many kinds of vegetables as palak, brinjal, sponge groung, amaranthus, radish, cauliflower, bottle gourd, pumpkin, lady's finger, pointed gourd, cabbage, bitter gourd, and tomato. The daily intake rates (g $person^{-1}day^{-1}$) of each heavy metal in vegetables were almost higher than the potential tolerable daily intake from FAO/WHO. Hazard quotient of Cd, Cu, Pb, Zn, Ni, and Cr from vegetables were almost less than one but all summations of each heavy metal from each vegetable were more than one. Thus the hazard index of palak, brinjal, sponge groung, amaranthus, radish, cauliflower, bottle gourd, pumpkin, lady's finger, pointed gourd, cabbage, bitter gourd, and tomato were 22.7, 7.7, 8.9, 13.0, 3.2, 6.9, 4.7, 5.7, 16.4, 1.7, 32.2, 4.0, and 4.6, respectively. To sum up, the case study got non-carcinogenic risk from vegetables via ingestion.

Muhammad, et al. (2011) studied heavy metals in drinking water of Kohistan, northern Pakistan. Heavy metals can expose to human body via serveral pathways, but in this study calculated the risk only ingestion route by drinking water. The concentrations of Cr, Cu, Co, and Mn were in acceptable level when refered with WHO and Pak EPA but the concentrations of Cd, Ni, Pb, and Zn were higher than acceptable level in 7%, 2%, 29%, and 6%, respectively. Thus the drinking water in this area should not be drunk because the concentration of some heavy metals were higher than safety level but can used for drinking if water was treated in acceptable level.

CHAPTER III
METHODOLOGY

3.1 Study design

This research was designed as shown conceptual framework in Figure 3.1. Qualitative risk assessment was use to assesse rapidly for risk estimation of incense workers in local area. Hazard identification was selected Ba, Cd, Cr, Mn, Ni, and Pb. The general information, working information, and general health were asked in the questionnaire to put some parameters in DAD equation and calculated HQ and HI values and then assess the risk to recommend in the risk management. The study was done from October 2011 to May 2012 and approved by the Ethical Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University, Thailand with the certificate code No.053/2012.

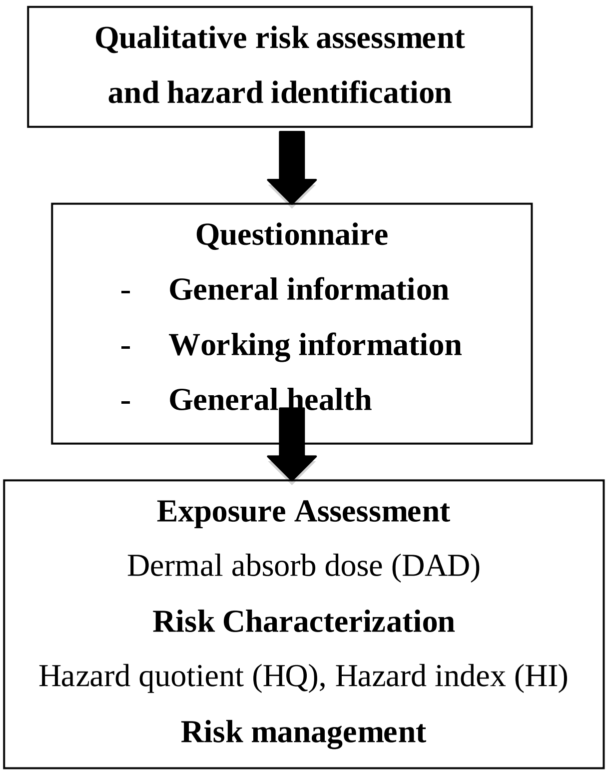


Figure 3.1 Conceptual framework of this study

3.2 Study area

Ngooleum village, in one of the largest of incense stick production in the northeastern region where located in Roi Et province, Thailand. The village was selected in the study and shown in Figure 3.2.

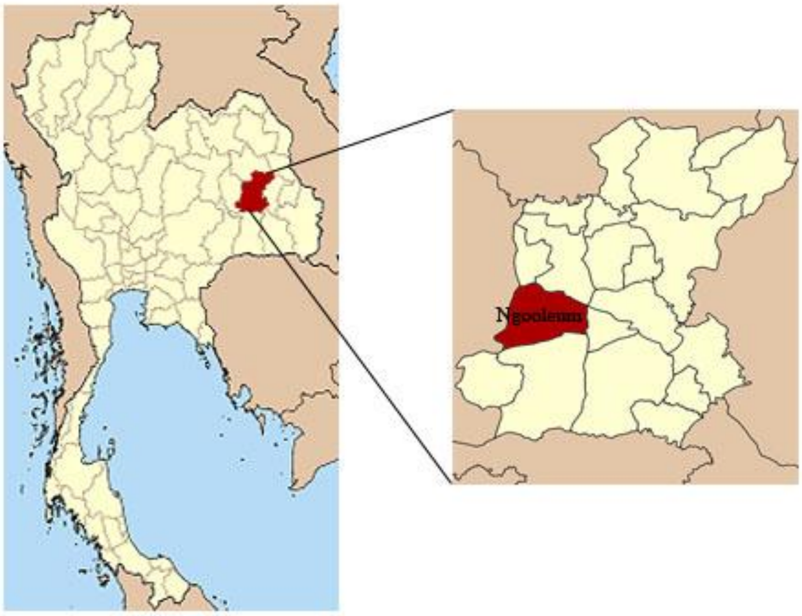


Figure 3.2 The study area, Ngooleum village, Dongdang subdistrict, Chaturaphakphiman district, Roi Et province, Thailand.

Roi Et province has 20 districts, the districts are subdivided into 193 sub districts and 2,311 villages. Ngooleum, a village in Dongdang sub district, Chaturaphakphiman district, is located in the east of Chaturaphakphiman district office. The village has total area of 2,380 rai separated into 200 rai of residential area and 2,180 rai of workplace. (Ministry of interior, 2011)

In 1957, most of working ages went to Bangkok, where is the capital of Thailand, to work as employee for supporting their families. Incense stick working was popular occupation of them. Fifteen years later, working ages came back to their hometown and used the experience from the incense stick working to produce incense stick on their own. Many years later, profit of incense stick producing was slightly decreased because incense stick industry expanded more than the past. Leader of Moo

5 of Ngooleum village set up the incense stick organization and invited villagers cooperated together for lowering cost of material for incense stick process in 2003.

In the case study Moo 12 of Ngooleum village was chosen because it earns the best income from incense household factory and incense making is the main occupation of villagers. Other occupations are farmer and shallot growing, so villagers grow in-season rice that means grow rice one time per year related to rain season during May to October. Some families in the village grew shallot to support their income. Those two occupations need not much attention, they can grow up naturally, and sometime fertilizers are applied.

3.2 Site observation and sampling collection

The incense making process was studied to consider the risk of dermal contact of each step and photos were taken to explain clearly incense making steps. Moo 12 of Ngooleum village had around 100 small household factories that making incense stick. Each small household factory had at least 5 incense workers, so male workers worked all of duties but incense packing step always work by female workers. Thirty-five small household factories were selected randomly by house number were representative groups of incense workers in the study area. Thirty sampling (n=30) is the least number in order to make a good estimation for population mean, so the case study selected 35 incense workers (Jaipieam, 2008; Ling, 2012). Each small household factory were collected the three sample groups as dissolved dye, incense stick, and hand wiping samples. The hand wiping technique was used to collected hand wiping samples from workers' hands. The diagram of sample collection was showed in Figure 3.3.

A worker who packs incense from each small household factory should work on incense process at least 1 year. Each small household factory was selected one worker randomly to wipe hands three or four events, which started in morning to lunch or afternoon. Table 3.1 showed the number of hand wiping samples of each event that were collected from incense packing workers.

- *Before working event*

The event started around 8 a.m. and collected hand wiping samples before incense workers worked on packing incense process.

- *After working by non using gloves*

The event was collected hand wiping samples at lunch when incense workers finish on packing incense during morning.

- *After washing hands*

Normally, incense workers washed their hands before having lunch. Thus the event was collected hand wiping samples after incense workers washed their hands.

But only 10 of 35 small household factories were selected randomly and collected hand wipe samples four events during morning to afternoon, so the forth event that was added as follow:

- *After working by using gloves*

The event was collected hand wiping samples after incense workers finish working on incense packing process by using gloves during working. This event was used to compare the heavy metal concentrations on workers' hands between after working by non using gloves and using gloves during working.

The dissolved dye, incense stick, and hand wiping samples of each small household factory came from the same dissolved dye, which workers mix it every day. The heavy metal concentration of three sample groups were considered the average concentration difference between dissolved dye and incense stick, dissolved dye and hand wiping sample, and incense stick and hand wiping sample. Moreover, the heavy metal concentrations, which were collected from different events, can compare the heavy metal concentrations.

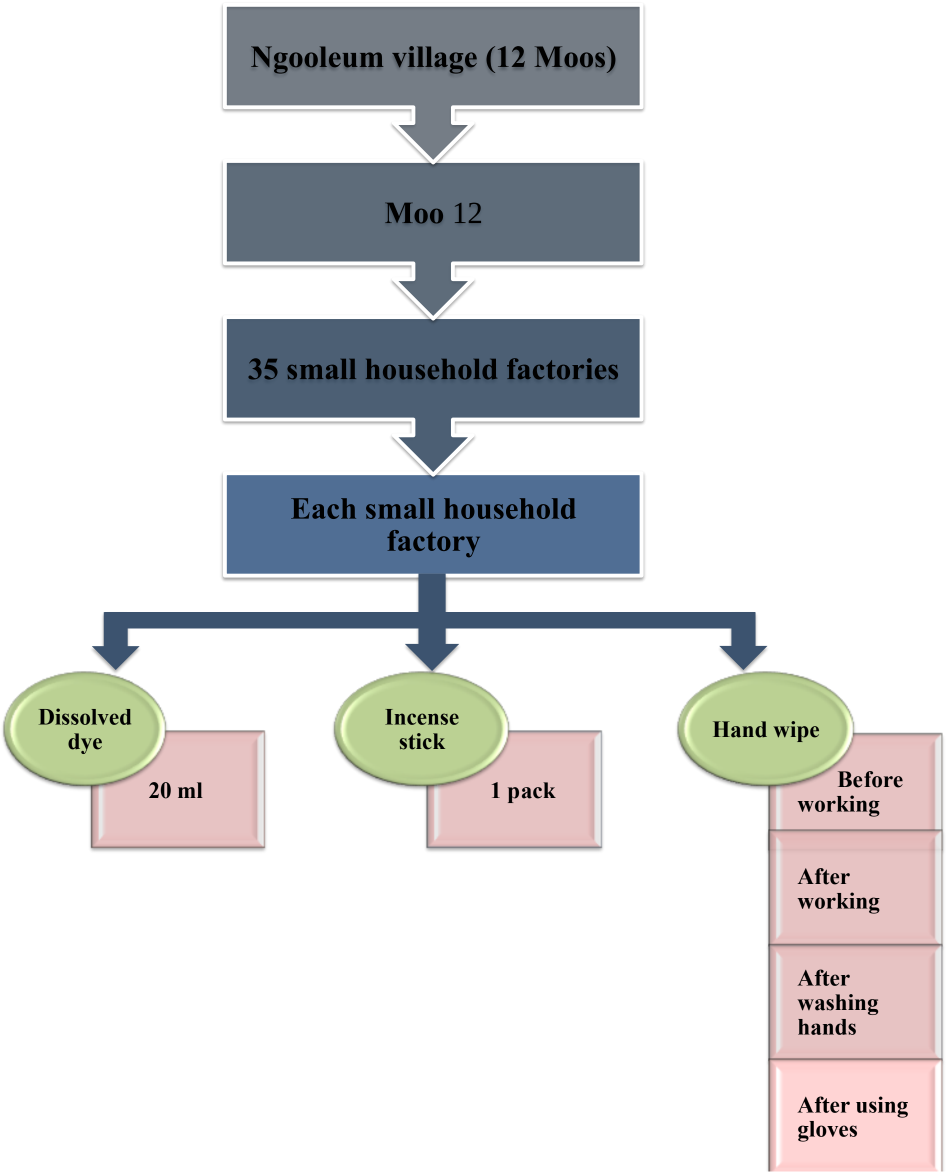


Figure 3.3 The diagram of sample collection at incense household factory

Table 3.1 The number of hand wiping samples

Workers (n)	Sample collection			
	Morning			Afternoon
	Before working	After working	After washing hands	After working (Using gloves)
25	▯	▯	▯	-
10	▯	▯	▯	▯

A questionnaire for dermal exposure survey of heavy metal in Ngooleum village, Dongdang sub district, Chaturaphakpiman district, Roi Et province, Thailand was shown in Appendix A as English and Thai versions. Thirty-five participants were chosen randomly from each small household factory for wiping and question them face-to-face in the morning before workers started working on incense packing process. In addition, the questionnaire was used to ask other workers in the incense stick process in the Moo 12 total as 100 workers including 35 wiped subjects. Sixty-five incense workers came from general workers and were selected randomly 1 or 2 workers from each small household factory. The questionnaire included age, gender, frequency of incense working, and sign and symptom of dermal contact. The questionnaire is divided into 3 parts as follows:

Part 1: General information of incense workers who pack the incense stick products, so this part has detail about name, age, gender, address, body weight, and height.

Part 2: Working information is the important part to know historical incense working of workers as duration of working (years), incense working (times/day), incense working period (hr/day), another working, gloves using, hands washing and cleaning.

Part 3: General health is question about health symptoms such as medicine allergy, hand eczema, skin rash, cramp, vomit, sweat and inconvenient breathing.

3.3 Sampling

The exposure survey was conducted from October 2011 to January 2012 and sample collection was collected on May 2012.

3.3.1 Dissolved dye

Each dissolved dye sample was mixed in different ratio from each small household factory, so thirty-five dissolved dye samples were collected from thirty-five small household factories and used polyethylene bottle to collect the samples 20 ml for measurement heavy metal concentrations.

Figure 3.4 Dissolved dye samples in Ngooleum village, Roi Et province, Thailand

3.3.2 Incense stick

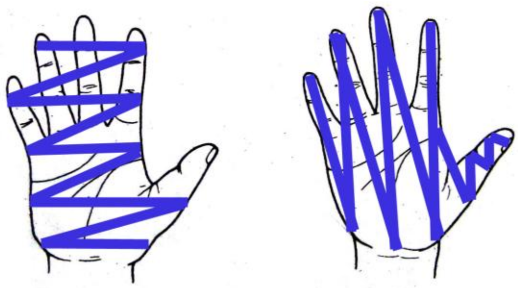
Incense stick samples were collected 35 packs from 35 small household factories that were dipped with the same dissolved dye of each small household factory. Moreover, original bamboo bundles that not dip anything were collected 5 bundles to quantify background of heavy metals in quality control part.

Figure 3.5 Incense stick samples in Ngooleum village, Roi Et province, Thailand

3.3.3 Hand wiping sample

Hand wiping samples were collected from 35 incense packing workers and used 20% isopropanol (Duggan, 1985) Gauze Pads wiped the hand surface, side to side of vertical and horizontal axis in “Z” wipe pattern. One hand was wiped 10 seconds on front side as well as back sides and applying to wipe fingers (ASTM D 6966-08, 2008). Then the samples were contained in zip-lock bags. Figure 3.6 shown workers’ hands before incense workers were collected samples and hand wiping technique, so the Z patterns were shown in Figure 3.7.

Figure 3.6 Incense packing workers’ hands and hand wiping technique



“Z” vertical “Z” horizontal

Figure 3.7 The Z patterns to wipe hand surface of front and back sides of two hands

Figure 3.8 Hand wiping samples in Ngooleum village, Roi Et province, Thailand

3.4 Metals analysis

All samples were digested and analyzed at Center of excellence for environmental and hazardous waste management, Chulalongkorn University by microwave digestion machine and inductively coupled plasma optical emission spectrometry, VISTA-MPX Axial (ICP-OES) respectively. Digestion method can digest the target heavy metals in this the study including barium (Ba), cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni), and lead (Pb). Moreover, ICP can analyze several metals per one time so include all of the six heavy metals (Cao et al, 2010) and (Wcislo et al, 2002). The concentrations of heavy metal were calculated in milligram per liter (mg/L) and milligram per kilogram (mg/kg) or ppm and the detection limit of each heavy metal was 0.005 mg/kg, except for lead that was 0.001 mg/kg.

3.4.1 Microwave digestion

The dissolved dye, incense stick, and hand wiping samples were digested by microwave digestion. The instructions of microwave using were same in every sample but the weight, chemical reagents, and condition of samples were different. Table 3.2 shown the condition of microwave digestion for dissolved dye, incense stick, and gauze wiping samples. Before using microwave digestion, the solid samples should be grinded to digest heavy metal out easily. For dissolved dye, using pipet sucked 250 µl of the samples. For incense stick and hand wiping samples, weighed grinded incense stick 0.5g and hand wiping samples 0.3g, respectively into polyethylene vessels then the polyethylene vessels were composed into HTC safety shield. The chemical reagents of each sample that shown in Table 3.2 were added into the polyethylene vessels then closed the vessel by using the torque wrench to tight them. The segments were inserted into microwave cavity and connect the temperature sensor then ran the microwave program depending on types of sample that shown in Table 3.2. When finish all of steps in microwave digestion, cooling the rotor by air or water until the solutions in the polyethylene vessel down to room temperature. After that, the vessels were opened and filtrated the solutions by Whatman No. 41 filter paper on glassed cone with 25 ml volumetric flask. After the solutions were adjusted, contained the solution into polyethylene bottle for quantitation the heavy metal concentrations in the next step.

Table 3.2 The condition of microwave digestion for dissolved dye, incense stick, and gauze wiping samples

Method	Sample	Reagents	(ml)	Microwave program							
				Step1		Step2		Step3		Step4	
				Min	^oC	Min	^oC	Min	^oC	Min	^oC
Dye	250 µl	65% HNO_3 30% H_2O_2 NH_4Cl	9 1 0.3g	10	220	15	220	-	-	-	-
Incense	0.5 g	65% HNO_3 30% H_2O_2	8 2	2	85	5	145	3	200	20	200
Gauze	0.3g	65% HNO_3	10	10	210	25	210	-	-	-	-

3.4.2 Analysis and identification of metal residues

After digesting and extracting the samples until become transparent solution, the digested samples were analyzed by inductively coupled plasma optical emission spectrometry, VISTA-MPX Axial (ICP-OES) to estimate the type and the concentrations of heavy metals. Mixed standard (23 elements) was used to evaluate heavy metal as barium (Ba), cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni), lead (Pb).

3.5 Quality control

All sample were digested by microwave digestion, so the condition of digestion were different (Table 3.2). For quality control part, the first step was quantification the heavy metal concentration background of each sample. The known heavy metal standards at low and high concentrations were spiked into the polyethylene vessels together with chemical reagents. When finished all of microwave digestion steps, the digested samples were contained in polyethylene bottles to quantify heavy metal concentration by inductively coupled plasma optical emission spectrometry, VISTA-MPX Axial (ICP-OES). Before measurement the heavy metal concentration, the calibration curves were made. The calibration curves were used heavy metal mix standard and were measured concentration at 0.001, 0.005, 0.05, 0.5, 1.0, 3.0, and 5.0 mg/L. The correlation coefficients of each heavy metal was greater than 0.99. Quality control was calculated the values by the equations in Appendix B and the values were as follow:

- *Detection limits*:

a) Limit of detection (LOD) is the lowest concentration of analyzes that can be detected at a known confidence level. The known standards were quantified 10 samples, so the results showed that LOD of Ba, Cd, Cr, Mn, and Ni were 0.005 mg/L but Pb was 0.001 mg/L

b) Limit of quantification (LOQ) the lowest concentration of analyzes that can be quantified a range of concentration at a known confidence level. From the equation in Appendix B, LOQ of Ba, Cd, Cr, Mn, and Ni were 0.05mg/L except Pb was 0.01 mg/L.

- *Precision and accuracy*:

a) Precision of the analysis uses percent precision or relative standard deviations (RSDs) to assess the replicate samples. The RSDs of heavy metals in dissolved dye, incense stick, and gauze pad samples were in the range of 3.8 to 9.3%, 4.1 to 9.0%, and 5.4 to 8.9%, respectively. In Table 3.3 showed RSDs of dissolved dye, incense, and gauze pad..

b) Accuracy of the analysis uses percent recovery to calculate the correct of the method of the analysis. The reasonable method recoveries of those heavy metals in dissolved dye, incense stick, and gauze-wiping pad were in the range of 85.3 to 97.3%, 85.5 to 99.7%, and 89.4 to 102.6%, respectively. In Table 3.3 showed recovery percent of dissolved dye, incense, and gauze pad samples.

Table 3.3 The average quality control of dissolved dye, incense, and gauze pad

HM	**Dissolved dye**		**Incense stick**		**Gauze pad**	
	Recovery %	**RSD %**	**Recovery %**	**RSD %**	**Recovery %**	**RSD %**
Ba	97.29	6.59	99.00	4.83	101.95	7.80
Cd	92.25	4.65	85.46	5.83	94.83	7.29
Cr	93.86	8.26	99.67	6.25	89.44	6.78
Mn	85.27	4.45	99.13	8.54	98.17	5.66
Ni	90.13	6.18	95.44	8.12	95.14	6.97
Pb	94.22	5.52	99.69	5.53	102.56	6.51

3.6 Health risk assessment

Health risk assessment in the case study considered in non-carcinogenic risk from heavy metal in dyeing color all of parameters in equation 2.1, 2.2, 2.3 were got from questionnaire and default value from US EPA. The values were calculated at mean and 95^{th} percentile by using SPSS for Mac (Version 20.0).

3.6.1 Hazard identification

Many literature reviews found heavy metal in dyeing color, so incense stick that dipped with dissolved dye containing heavy metals. Incense packing workers exposed heavy metal via dermal contact when worked on the process. The risk of heavy metal via dermal route was non-carcinogen.

3.6.2 Dose-response assessment

The dermal reference dose (RfD_d) (mg/kg-day) of Ba, Cd, Cr, Mn, Ni, and Pb were shown in Table 2.5.

3.6.3 Exposure assessment

dermal absorb dose (DAD) equation 2.1 to calculate the chemical dose that workers got from exposure incense stick and the reference equation from United States Environmental Protection Agency (US EPA, 2004).In equation 2.1 equation had to know parameters as event per day (EV), exposure duration (ED), exposure frequency (EF), body weight (BW), and averaging time (AT), which can got direct values from the questionnaire. For DAevent formula, heavy metal concentration (C) can got from laboratory by using microwave digestion and inductively coupled plasma optical emission spectrometry, (ICP-OES), but dermal absorption fraction (ABS_d) could be got the default values from US EPA (see in Table 2.5), adherence factor of soil to skin (AF) at average and 95^{th} percentile were 0.001 and 0.003 mg/ cm^2- event) (US EPA, 2004).

Conversion factor (CF) was 10^{-6} kg/mg. Weight (W) and height (H) of incense workers were asked in the questionnaire and used the direct value to calculate surface area (SA), so male and female are different in default value of a_0, a_1, and a_2 (US EPA, 1997 see in table 4.6). The calculations were divided into three groups as male (n=5), female (n=30), and total workers (n=35)

3.6.4 Risk characterization

The dermal reference doses (RfD_d) of heavy metals in Table 2.5 were compared with dermal absorb dose (DAD) to calculate HQ and HI value in equation 2.5 and 2.6. If HQ or HI values more than 1, the dermal exposure may be got non-carcinogenic risk.

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Participant information

The study area was Moo 12 of Ngooleum village in Roi Et province, Thailand. There are around 100 small household factories, but thirty-five small household factories were selected randomly to collect dyeing color, incense stick, and heavy metal residues on one packaging worker's hands of each factory. Hand wiping samples were collected from 35 incense-packing workers, which were selected randomly. One hundred participants were asked face to face in the questionnaire; so the participants come from the 35 incense-packing workers and sixty-five participants that were selected randomly from 35 small household factories. Thus, in this part was reported in three sections as (1) general information, (2) participant and duty in workplace process, and (3) personal protective equipment (PPE) and self-cleaning. One hundred participants (n =100) were considered into two groups as 65 male participants (65%), and 35 female participants (35%). The details of information were reported in percentage of each group. The data were illustrated in Table 4.1 and Table 4.2, Table 4.3, and Table 4.4.

4.1.1 General information

In the village, the majority age of male, female and total participants were in the range of 31-40 years (29.2%, 37.1%, and 32%, respectively). The majority weight of male and female were different, so male in the range of 51-60 kilograms (49.2%) and female was 61-70 kilograms (31.4%). The main height of male in the range of 161-170 centimeters (43.1%) and female was 151-160 centimeters (48.6%). The almost education level of male and female participants were elementary school (52.3% and 42.9%, respectively). Participants always work in incense working, framer, employee, and merchant, but the main occupations of total participants were incense worker and farmer, so this group was 61% of total participants.

Table 4.1 General information of incense workers in Moo 12 of Ngooleum village in Roi Et province, Thailand (n=100)

Characteristics	Incense workers					
	Male		Female		Total	
	(n=65)	%	(n=35)	%	(n=100)	%
Age						
≤ 20	16	24.6	5	14.3	21	21
21-30	11	16.9	8	22.9	19	19
31-40	19	29.2	13	37.1	32	32
41-50	15	23.1	6	17.1	21	21
≥51	4	6.2	3	8.6	7	7
Body Weight (kilograms)						
≤ 50	8	12.3	10	28.6	18	18
51-60	32	49.2	10	28.6	42	42
61-70	16	24.6	11	31.4	27	27
≥ 71	9	13.8	4	11.4	13	13
Height						
≤ 150	1	1.5	11	31.4	12	12
151-160	19	29.2	17	48.6	36	36
161-170	28	43.1	7	20	35	35
≥ 171	17	26.2	0	0	17	17
Education						
Illiteracy	1	1.5	0	0	1	1
Elementary school	34	52.3	15	42.9	49	49
Junior high school	19	29.2	12	34.3	31	31
Senior high school	10	15.4	8	22.9	18	18
Bachelor’s degree, or above	1	1.5	0	0	1	1
Occupation						
Incense producer	10	15.4	1	2.9	11	11
Student	0	0	1	2.9	1	1
Incense producer/Farmer	36	55.4	25	71.4	61	61
Incense producer/Farmer/Merchant	10	15.4	2	5.7	12	12
Incense producer/Farmer/Employee	9	13.8	6	17.1	15	15

4.2 Participant and duty in workplace process

Although there are many occupations in Moo 12 of Ngooleum village, incense stick making is the majority occupation so all participants worked 5-7 days per week in incense process (100.0%). The six steps of incense making process are (1) bamboo preparing, (2) incense powder mixing, (3) incense molding, (4) color dipping and drying, (5) perfume spraying, and (6) incense packing. For male participants, the majority duties were the bamboo preparation, incense powder mixing, and color dipping and dying (32.3%). Female participants always work in only incense packing (85.7%), so in chapter III indicated the participants who were selected randomly to wipe their hands were 30 female and 5 male participants. If considering in total participants, the three main duties were (1) incense packing (30.0%), (2) bamboo preparation, incense powder mixing, and color dipping and dying (21.0%), and (3) incense powder mixing and color dipping and dying (16.0%).

Table 4.2 Duty information of incense workers in Moo 12 of Ngooleum village in Roi Et province, Thailand (n=100)

Characteristics	Incense workers					
	Male		Female		Total	
	(n=65)	%	(n=35)	%	(n=100)	%
Incense working (days/week)						
5-7 days/week	65	100	35	100	100	100
Duty(s) in Incense Making Process						
Incense powder mixing	7	10.8	0	0	7	7
Incense packing	0	0	30	85.7	30	30
Incense powder mixing/Color dipping and dying	16	24.6	0	0	16	16
Incense powder mixing/Incense packing	0	0	1	2.9	1	1
Perfume spraying/Incense packing	0	0	1	2.9	1	1
Bamboo preparation/Incense powder mixing/Color dipping and dying	21	32.3	0	0	21	21
Bamboo preparation/Incense powder mixing/Incense molding	1	1.5	0	0	1	1
Incense powder mixing/Color dipping and dying/Incense packing	4	6.2	0	0	4	4
Incense powder mixing/Incense molding/Color dipping and dying	4	6.2	0	0	1	1
Bamboo preparation/Color dipping and dying/Perfume spraying/Incense packing	1	1.5	0	0	5	5
Bamboo preparation/Incense powder mixing/Incense molding/Color dipping and dying	4	6.2	0	0	4	4
Incense powder mixing/Incense molding/Color dipping and dying/Incense packing	1	1.5	0	0	1	1
Incense powder mixing/Color dipping and dying/Perfume spraying/Incense packing	3	4.6	2	5.7	5	5
All of duties	3	4.6	1	2.9	4	4

In dermal absorb dose (DAD) equation have to use many parameters to calculate the value, body weight (BW) and height (H) in Table 4.1 and incense working in term of day per week (EF) in Table 4.2 were used. In this part was showed other parameters as exposure duration (ED) and incense working in term of event per day (EV) and hour per day. The data showed that 44.6% of male participants had work less than 11 years, 30.8% had work 11-20 years, and 24.6% had work 21-30 years. Female participants had work less than 11 years was 28.6% , 42.9% had work 11-20 years , 25.7% had work 21-30 years, and 2.9% had work more than 30 years. For one day, male participants work in incense process 1 event (47.7%), 2 events (50.8%), and 3 events (1.5%). Female participants work in incense process 1 event (42.9%), 2 events (40.0%), and 3 events (17.1%). If working considering in hour per day, male participants worked 3.5-6 hours per day (61.5%) and 38.5% was more than 6 hours. Thus incense working in term of hours per day of male participants was different with female participants, 28.6% of female participants worked 3.5-6 hours per day, but 71.4% of female participant worked more than 6 hours per day.

Table 4.3 Exposure information of incense workers in Moo 12 of Ngooleum village in Roi Et province, Thailand (n=100)

Characteristics	**Incense workers**					
	Male		**Female**		**Total**	
	(n=65)	**%**	**(n=35)**	**%**	**(n=100)**	**%**
Duration Time of Incense Making						
≤ 10	29	44.6	10	28.6	39	39
11-20	20	30.8	15	42.9	35	35
21-30	16	24.6	9	25.7	25	25
≥ 31	0	0	1	2.9	1	1
Incense working (Event/day)						
1	31	47.7	15	42.9	46	46
2	33	50.8	14	40.0	47	47
3	1	1.5	6	17.1	7	7
Incense working (hours/day)						
3.5-6	40	61.5	10	28.6	50	50
≥6	25	38.5	25	71.4	50	50

4.3 Personal Protective Equipment (PPE) and self-cleaning

During working incense process, 53.8% of male participants had dyeing color left on their hands and 46.2% did not have dyeing color left on their hands. However, 100% of female participants had dyeing color left on their hands because almost incense packing workers were female and the duty was the main risk to contact dyeing color. For personal protective equipment (PPE), gloves was concerned in the case study but both male and female participants had no using gloves when working. Thus this study was designed to measure heavy metal residues on workers' hands after using gloves and compared with non using gloves (see in chapter 3). Self-cleaning of the case study was concerned in times to washing hands and washing types. Male participants washed their hands after working 1-2 times per day was 10.8% but 10.8% of male participants washed their hands 1-2 times per day. All female participants washed hands 3-4 times per day (100.0%). Washing types that male participants using were water (44.6%), soap (53.8%), and dishwashing liquid (1.6%). The trend of washing types for female participants way same as the male participants. The washing types of female participants were water (22.9%), soap (65.7%), and dishwashing liquid (11.4%).

Table 4.4 PPE and self-cleaning information of incense workers in Moo 12 of Ngooleum village in Roi Et province, Thailand (n=100)

Characteristics	Incense workers					
	Male		Female		Total	
	(n=65)	%	(n=35)	%	(n=100)	%
Dyeing Color Left on Body						
Yes	35	53.8	35	100	70	70
No	30	46.2	0	0	30	30
Use Gloves						
Yes	0	0	0	0	0	0
No	65	100	35	100	100	100
Washing hands per day						
1-2	7	10.8	0	0	7	7
3-4	58	89.2	35	100	93	93

Washing type

Characteristics	Incense workers					
	Male		Female		Total	
	(n=65)	%	(n=35)	%	(n=100)	%
Water	29	44.6	8	22.9	37	37
Soap	35	53.8	23	65.7	58	58
Dishwashing liquid	1	1.6	4	11.4	5	5

The exposure information of thirty-five workers who were wiped their hands was used to calculate the risk. The average exposure frequency (days/year), and exposure duration (year) were 365 days of both genders, 19 ± 2.24 years in male and 18.7 ± 9.55 years in female. The averages of event per day for male and female participants were 1.5 and 1.7 events, respectively.

Table 4.5 The average exposure parameter information of thirty-five incense-packing workers (n=35)

Exposure variation	Mean (±SD)	
	Male	Female
Average exposure frequency (days/year)	365	365
Average exposure duration (year)	19 ± 2.24	18.7 ± 9.55
Average event/day (event)	1.5	1.7

4.4 Hand surface area

From dermal absorb dose (DAD) equation in exposure assessment step (chapter II), it has surface area parameter in the equation. Although surface area of each part has constant value from the U.S. Environmental Protection Agency (US EPA) (US EPA, 1997), the case study use the real surface area value (Taneepanichskul, 2009) because the constant value is not suitable for Asian, the real value from incense workers made DAD results are more correctly. The calculation of surface area use height and weight of the subject in the case study is as follow:

$$SA= a_0H^{a1}W^{a2}$$

Where

SA = surface area (m^2)

H = height (cm)

W = weight (kg)

a_0, a_1, and a_2 = Constant values (US EPA,1997)

The calculation was separated into two groups as male and female participants because a_0, a_1, and a_2 constants values are different (see table 4.3), so surface area value was calculated only thirty-five packing incense workers who were wiped their hands. The average height and weight of male participants (n=5) were 167.20 centimeters and 64.20 kilograms, respectively. The average height and weight of female participants (n=30) were 156.0 centimeters and 58.26 kilograms, respectively. Thus, the average hand surface area values of male and female were 0.091 and 0.080 m^2.

Table 4.6 The average hand surface area of incense-packing workers in Moo 12 of Ngooleum village, Roi Et province, Thailand

Sex	**Average height (cm)**	**Average weight (kg)**	**a_{0*}**	**a_{1*}**	**a_{2*}**	**Hand surface area (m^2)**
Male (n=5)	167.20	64.20	0.0257	0.573	-0.218	0.091
Female (n=30)	156.00	58.26	0.013	0.412	0.0274	0.080

*a_0, a_1, and a_2 are default values from US EPA (US EPA, 1997)

4.5 Extraction of heavy metals in dissolved dye, incense stick, and heavy metal residue in hand wipe samples

4.5.1 Heavy metals concentration of dissolved dye, incense stick, and hand wipe samples

In the case study of Ngooleum village, Chaturaphakpiman district, Roi Et province, Thailand, the three sample groups were collected to quantify heavy metal concentrations and consider the mean difference among dissolved dye, incense stick, and hand wiping sample by using ANOVA (Post hoc LSD).

There are 100 small household factories in Moo 12 of Ngooleum village, so in the study selected randomly 35 household factories were representatives of this area. Each small household factory was collected 20 ml of dissolve dye, 1 pack of incense stick, and 3 or 4 hand wiping samples. Incense workers whom wipe their hands were incense packing workers and the workers were selected randomly from each small household factory to measure heavy metal residues. To know the heavy metal concentration, two steps as sample digestion and sample analysis steps were used. All samples were digested by microwave digestion and used the method that suitable for each sample (see in chapter III). Inductively coupled plasma optical emission spectrometry, VISTA-MPX Axial (ICP-OES) was used in sample analysis step to identify and measure concentration of six heavy metals.

The average concentration (standard deviation (±SD)) of Ba, Cd, Cr, Mn, Ni, and Pb in dissolved dye were 1.47 ± 0.21 mg/L, 0.16 ± 0.01 mg/L, 1.34 ± 0.13 mg/L, 1.12 ± 0.10 mg/L, 0.64 ± 0.08 mg/L, 0.90 ± 0.05 mg/L, respectively (Table 4.7 and Figure 4.1). The average concentration (±SD) of Ba, Cd, Cr, Mn, Ni, and Pb in incense stick were 1.30 ± 0.29 mg/kg, 0.08 ± 0.03 mg/kg, 0.89 ± 0.10 mg/kg, 0.87 ± 0.13 mg/kg, 0.99 ± 0.19 mg/kg, 0.27 ± 0.05 mg/kg, respectively (Table 4.7 and Figure 4.2). The average residue concentrations (±SD) of Ba, Cd, Cr, Mn, Ni, and Pb on worker's hands were 11.03±2.31 mg/kg, 1.13±0.23 mg/kg, 2.77±0.83 mg/kg, 7.06±1.92 mg/kg, 8.20±2.22 mg/kg, and 3.55±1.32 mg/kg, respectively (see in Table 4.7 and Figure 4.3). The average heavy metal concentration of dissolved dye, incense stick, and hand wiping samples were compared together by using ANOVA. The mean difference of Ba, Cd, Cr, Mn, Ni, and Pb of the three groups were statistically significant (*p*=0.000) (see in Table 4.8). The result means at least one paired sample was statistically significant difference. Thus Post hoc LSD was used to compare the average heavy metal concentrations in paired sample between dissolved dye and incense stick, dissolved dye and hand wiping sample, and incense stick and hand wiping sample. The results showed the mean difference of Ba, Mn, and Ni between dissolved dye and incense stick were not statistically significant (*p*=0.597, 0.339, and 0.261, respectively), but Cd, Cr, and Pb were statistically significant (*p*=0.000) (see in Table 4.9). The mean difference of Ba, Cd, Cr, Mn, Ni, and Pb for paired between dissolved dye and hand wiping sample were statistically significant (*p*=0.000) and incense stick and hand wiping sample were statistically significant (*p*=0.000) (see in Table 4.10 and 4.11, respectively). In Figure 4.4 showed the bar graph of the mean concentrations for dissolved dye, incense stick, and hand wiping samples with the different letter are significantly different at $p \leq 0.05$. When compared the mean heavy metal concentrations of dissolved dye and incense stick with hand wiping sample, the results found that were statistically significant because surface area of hands more than dissolved dye and incense stick. Another reason was during working incense process around 3-4 hours per event had accumulated dyeing color on hands.

If the heavy metal concentrations were considered in range, the concentration of Cd, Mn, and Ni of dissolved dye, was in the range of 0.14-0.19, 1.01-1.32, and 0.53-0.79 mg/L, respectively. The concentration of Cd, Mn, and Ni of incense stick and hand wipe were in the range of 0.05-0.24 and 0.61-1.55, 0.51-1.05 and 3.19-9.83, and 0.65-1.12 and 4.70-12.78 mg/kg, respectively. Tuzen et al. (2008) studied heavy metal concentration in many type of textile products in textile industry, Turkey. The concentrations of heavy metals in textile samples were found Cu, Cd, Zn, Mn, Fe, and Ni in the range of 0.76-341 μg/g, 0.10-0.25 μg/g, 0.63-4.84 μg/g, 1.02-2.50 μg/g, 3.55-34.3 μg/g, and 1.20-4.69 μg/g, respectively. The concentration of heavy metals as Cd, Mn, and Ni can be compared with the case study because the color on the incense bundle come from dyeing color like a dye in textile products. The Cd, Mn, and Ni concentrations of dissolved dye and incense stick and hand wiping samples were more than the previous study (Tuzen et al., 2008).

Table 4.7 The average concentration (standard deviation, ±SD) of heavy metals of dissolved dye, incense stick, and hand wiping samples from Ngooleum village, Roi Et province, Thailand

Elements	Heavy metal concentrations		
	Dissolved dye ±SD (mg/L)	**Incense stick ±SD (mg/kg)**	**Hand wipe ±SD (mg/kg)**
Ba	1.47 ± 0.21	1.30 ± 0.29	11.03 ± 2.31
Cd	0.16 ± 0.01	0.08 ± 0.03	1.13 ± 0.23
Cr	1.34 ± 0.13	0.89 ± 0.10	2.77 ± 0.83
Mn	1.12 ± 0.10	0.87 ± 0.13	7.06 ± 1.92
Ni	0.64 ± 0.08	0.99 ± 0.19	8.20 ± 2.22
Pb	0.90 ± 0.05	0.27 ± 0.05	3.55 ± 1.32

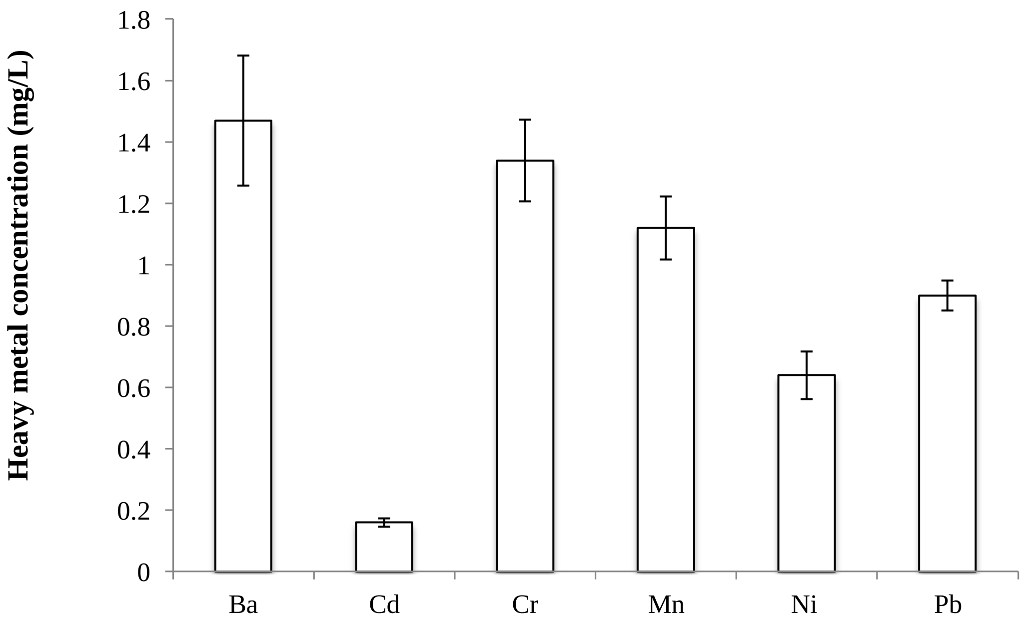


Figure 4.1 Heavy metal concentration of dissolved dye (mg/L) from thirty-five small household factories in Ngooleum village, Roi Et province, Thailand

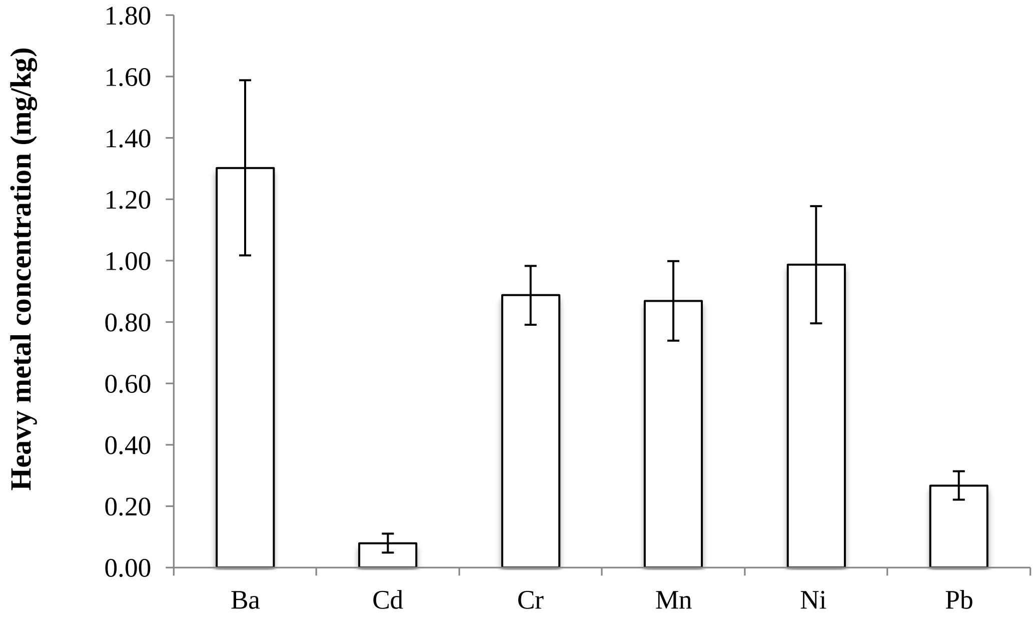


Figure 4.2 Heavy metal concentration of incense stick (mg/kg) from thirty-five small household factories in Ngooleum village, Roi Et province, Thailand

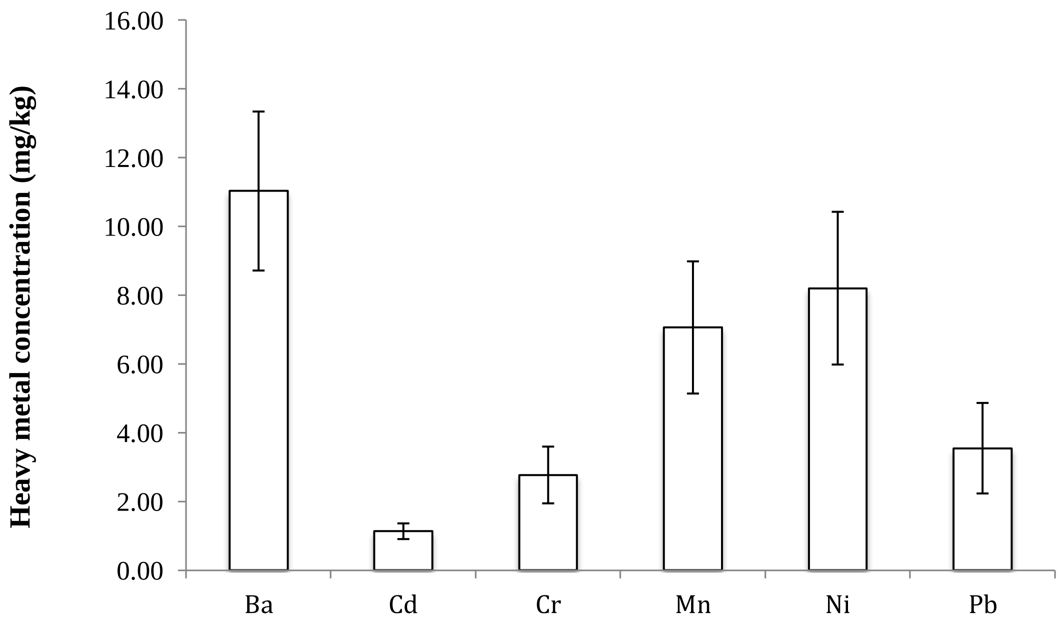


Figure 4.3 Heavy metal concentration of hand wipe samples (mg/kg) from thirty-five small workers in Ngooleum village, Roi Et province, Thailand

Table 4.8 The mean difference of the six heavy metals of three groups by ANOVA

Elements	Concentrations			*p* value
	Dissolved dye (±SD) (mg/L)	Incense stick (±SD) (mg/kg)	Hand wipe (±SD) (mg/kg)	
Ba	1.47 ± 0.21	1.30 ± 0.29	11.03 ± 2.31	0.000
Cd	0.16 ± 0.01	0.08 ± 0.03	1.13 ± 0.23	0.000
Cr	1.34 ± 0.13	0.89 ± 0.10	2.77 ± 0.83	0.000
Mn	1.12 ± 0.10	0.87 ± 0.13	7.06 ± 1.92	0.000
Ni	0.64 ± 0.08	0.99 ± 0.19	8.20 ± 2.22	0.000
Pb	0.90 ± 0.05	0.27 ± 0.05	3.55 ± 1.32	0.000

Table 4.9 The mean difference of the six heavy metals between dissolved dye and incense stick by Post hoc LSD

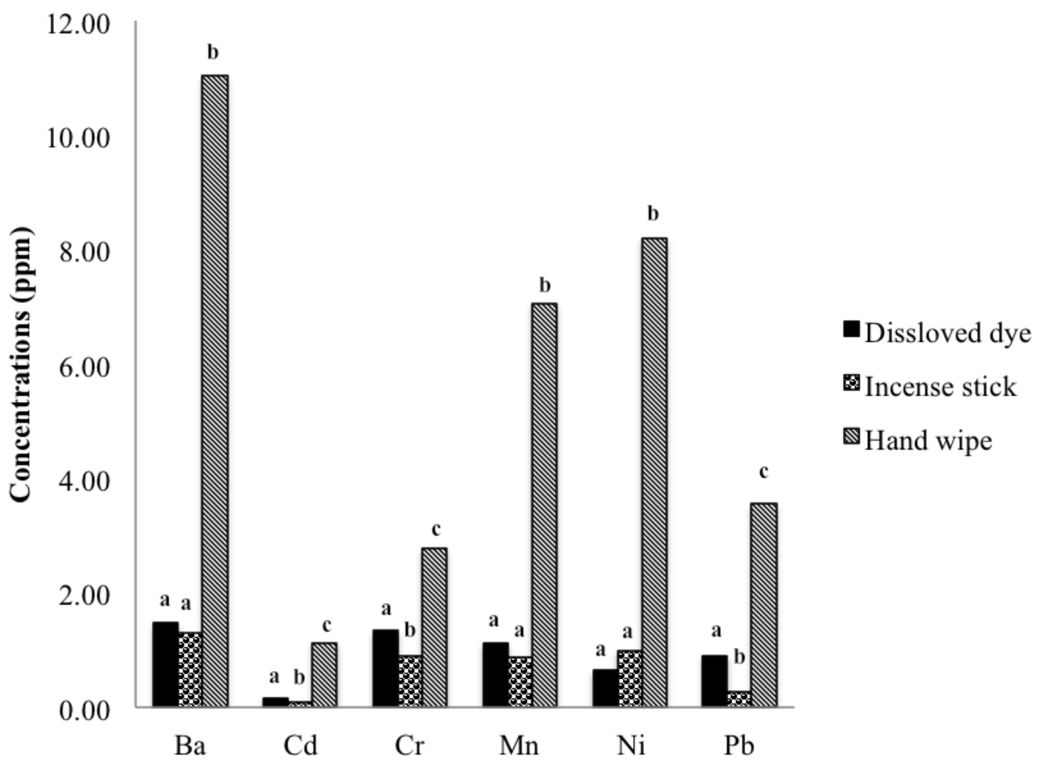
Elements	Concentrations		*p* value
	Dissolved dye (±SD) (mg/L)	Incense stick (±SD) (mg/kg)	
Ba	1.47 ± 0.21	1.30 ± 0.29	0.597
Cd	0.16 ± 0.01	0.08 ± 0.03	0.009
Cr	1.34 ± 0.13	0.89 ± 0.10	0.000
Mn	1.12 ± 0.10	0.87 ± 0.13	0.339
Ni	0.64 ± 0.08	0.99 ± 0.19	0.261
Pb	0.90 ± 0.05	0.27 ± 0.05	0.001

Table 4.10 The mean difference of the six heavy metals between dissolved dye and hand wiping sample by Post hoc LSD

Elements	**Concentrations**		***p* value**
	Dissolved dye (±SD) (mg/L)	**Hand wipe (±SD) (mg/kg)**	
Ba	1.47 ± 0.21	11.03 ± 2.31	0.000
Cd	0.16 ± 0.01	1.13 ± 0.23	0.000
Cr	1.34 ± 0.13	2.77 ± 0.83	0.000
Mn	1.12 ± 0.10	7.06 ± 1.92	0.000
Ni	0.64 ± 0.08	8.20 ± 2.22	0.000
Pb	0.90 ± 0.05	3.55 ± 1.32	0.000

Table 4.11 The mean difference of the six heavy metals between incense stick and hand wiping sample by Post hoc LSD

Elements	**Concentrations**		***p* value**
	Incense stick (±SD) (mg/kg)	**Hand wipe (±SD) (mg/kg)**	
Ba	1.30 ± 0.29	11.03 ± 2.31	0.000
Cd	0.08 ± 0.03	1.13 ± 0.23	0.000
Cr	0.89 ± 0.10	2.77 ± 0.83	0.000
Mn	0.87 ± 0.13	7.06 ± 1.92	0.000
Ni	0.99 ± 0.19	8.20 ± 2.22	0.000
Pb	0.27 ± 0.05	3.55 ± 1.32	0.000



a,b,c : The mean concentrations with the different letter are significantly different at p≤0.05

Figure 4.4 Comparison of heavy metal concentration of dissolved dye (mg/L), incense stick (mg/kg), and hand wipe samples (mg/kg) from thirty-five workers in Ngooleum village, Roi Et province, Thailand

4.5.2 **Heavy metals concentration on workers' hands during working**

Hand wiping samples collected by hand wiping technique to collect samples. The technique use 20% denatured alcohol gauze pad so adopted from HUD (HUD, 1995) and the previous studies that use the technique to collect lead dust samples on children's hands (Duggan, 1985) and household areas (Stering et al., 1999).

Thirty-five workers were separated into two groups, the first group had twenty-five workers (n=25) and the second group had ten workers (n=10). Twenty-five workers in the first group were collected three times of hand wiping samples as before working, after working, and after washing hands. Only ten workers in the second group were collected hand wiping samples four times, so after working by using gloves was added. The reasons why that hand wiping samples were collected many times because this part aimed to compare the average concentration of each heavy metal in difference events. First, all of heavy metal concentration values were tested normality and the results found that were not normality data. Thus this part used Willcoxon test to compare the average heavy metal concentrations. The average heavy metal concentrations during work at before working, after working, after washing hands, and after working by using gloves are showed in the table 4.12. There were four paired samples that were compared together. Paired of before and after working, the result was statistically significant difference (p=0.000) for all of heavy metals and the percentage of heavy metal concentration increasing in the range of 95.33-97.75% (Table 4.13). The average heavy metal concentrations of after working and after washing hands was statistically significant difference (p=0.000) for all of heavy metals, so the percentage of heavy metal concentration decreasing in the range of 88.09-97.18% (Table 4.14). Paired of before working and after washing hands, the mean difference of all heavy metals were statistically significant (p=0.000) except Pb (p=0.027) and the percentage of heavy metal concentration that remaining in the range of 15.38-68.18% (Table 4.15). The last paired was tested because in Table 4.4 the result indicated all participants did not use gloves when working. Thus after working by non-using gloves and using gloves were compared and the results showed that mean concentration of all heavy metals were statistically significant difference (p=0.000), so the percentage of heavy metal concentration that decreasing in the range of 97.11-99.76%. Therefore, the results indicated that using gloves can protect participants to expose heavy metals (see in Table 4.16).

This part was designed to consider heavy metal concentration and compared the average concentation of each hand wiping sample, so it was applied from the previous study of lead in playground dust and on the hands of schoolchildren (Duggan, 1985). In Duggan's study found that after play, the geometric mean (GM) of lead concentration of girls, boys, and all were 25 μg/child, 35 μg/child, and 29 μg/child, respectively. The lead concentration after washing hands of girls, boys, and all were 6.3 μg/child, 9.0 μg/child, and 7.4 μg/child, respectively. Another school, considered the GM of lead concentration at before play and after play. The result found that the lead concentration at GM of girls, boys, and all were 5.5 μg/child, 6.3 μg/child, and 5.9 μg/child, respectively at before play. For after play, the GM of lead concentration of girls, boys, and all were 20 μg/child, 22 μg/child, and 21 μg/child, respectively. In conclusion, when consider the lead concentration after play was reduce by washing hands and the lead concentration before play increased when measured the lead concentration after play. Thus, the trend of results from Duggan' study conform to the results in this part.

Table 4.12 The average concentrations of heavy metals of hand wipe samples during working from Ngooleum village, Roi Et province, Thailand

Elements	Average heavy metal concentration ±SD (mg/kg)			
	Before working*	**After working***	**After washing hand***	**Use gloves♠**
Ba	0.28 ± 0.15	11.03 ± 2.31	0.88 ± 0.39	0.08 ± 0.03
Cd	0.06 ± 0.04	1.13 ± 0.23	0.10 ± 0.06	0.02 ± 0.00
Cr	0.07 ± 0.05	2.77 ± 0.83	0.33 ± 0.15	0.08 ± 0.04
Mn	0.33 ±0.17	7.06 ± 1.92	0.48 ± 0.17	0.14 ± 0.01
Ni	0.33 ±0.18	8.20 ± 2.22	0.39 ± 0.17	0.02 ± 0.01
Pb	0.08 ± 0.05	3.55 ± 1.32	0.10 ± 0.04	0.03 ± 0.01

* Hand wiping samples of 35 workers (n=35), ♠ Hand wiping samples of 10 workers (n=10)

Table 4.13 The mean difference of heavy metal concentration between before working and after working (n=35)

Elements	Average concentration (±SD) (mg/kg)		*p* value	% Increase
	Before working	**After working**		
Ba	0.28 ± 0.15	11.03 ± 2.31	0.000	97.46
Cd	0.06 ± 0.04	1.13 ± 0.23	0.000	94.69
Cr	0.07 ± 0.05	2.77 ± 0.83	0.000	97.47
Mn	0.33 ±0.17	7.06 ± 1.92	0.000	95.33
Ni	0.33 ±0.18	8.20 ± 2.22	0.000	95.98
Pb	0.08 ± 0.05	3.55 ± 1.32	0.000	97.75

The mean concentrations are significantly different at $p \leq 0.05$

Table 4.14 The mean difference of heavy metal concentration between before working and after working (n=35)

Elements	Average concentration (±SD) (mg/kg)		*p* value	% Decrease
	After working	After washing hand		
Ba	11.03 ± 2.31	0.88 ± 0.39	0.000	92.02
Cd	1.13 ± 0.23	0.10 ± 0.06	0.000	91.15
Cr	2.77 ± 0.83	0.33 ± 0.15	0.000	88.09
Mn	7.06 ± 1.92	0.48 ± 0.17	0.000	93.20
Ni	8.20 ± 2.22	0.39 ± 0.17	0.000	95.24
Pb	3.55 ± 1.32	0.10 ± 0.04	0.000	97.18

The mean concentrations are significantly different at $p \leq 0.05$

Table 4.15 The mean difference of heavy metal concentration between before working and after working (n=35)

Elements	Average concentration (±SD) (mg/kg)		*P* value	% Remain
	Before working	After washing hand		
Ba	0.28 ± 0.15	0.88 ± 0.39	0.000	68.18
Cd	0.06 ± 0.04	0.10 ± 0.06	0.000	40.00
Cr	0.07 ± 0.05	0.33 ± 0.15	0.000	78.79
Mn	0.33 ±0.17	0.48 ± 0.17	0.000	31.25
Ni	0.33 ±0.18	0.39 ± 0.17	0.000	15.38
Pb	0.08 ± 0.05	0.10 ± 0.04	0.027	20.00

The mean concentrations are significantly different at $p \leq 0.05$

Table 4.16 The mean difference of heavy metal concentration between before working and after working (n=10)

Elements	Average concentration (±SD) (mg/kg)		*p* value	% Decrease
	After working (non gloves)	After working (using gloves)		
Ba	11.03 ± 2.31	0.08 ± 0.03	0.005	99.27
Cd	1.13 ± 0.23	0.02 ± 0.00	0.005	98.23
Cr	2.77 ± 0.83	0.08 ± 0.04	0.005	97.11
Mn	7.06 ± 1.92	0.14 ± 0.01	0.005	98.02
Ni	8.20 ± 2.22	0.02 ± 0.01	0.005	99.76
Pb	3.55 ± 1.32	0.03 ± 0.01	0.005	99.15

The mean concentrations are significantly different at $p \leq 0.05$

4.6 Health risk assessment

Health risk assessment in the case study considered in non-carcinogenic risk, so this part got exposure parameters in equations 2.1, 2.2, and 2.3 from direct values from questionnaires. Table 4.17 showed exposure parameters in DAD equation for workers at average concentration as well as Table 4.18 showed at 95th percentile.

Table 4.17 Exposure parameters in DAD equation for workers at average concentration in Ngooleum village, Roi-Et province, Thailand

Workers	SA* (cm^2)	EV (event/day)	ED (years)	EF (days/year)	BW (kg)	AT (days)
Male (n=5)	914.1	1.5	19	365	64.2	6935
Female (n=30)	803	1.7	18.7	365	58.3	6826
Total (n=35)	858.5	1.6	18.7	365	59.1	6826

*SA is value from direct calculation (Table 4.3)

Table 4.18 Exposure parameters in ADD equation for workers at 95th percentile concentration in Ngooleum village, Roi Et province, Thailand

Workers	SA* (cm^2)	EV (event/day)	ED (years)	EF (days/year)	BW (kg)	AT (days)
Male (n=5)	NC	NC	NC	NC	NC	NC
Female (n=30)	803	1.7	18.7	365	58.3	6826
Total (n=35)	858.5	1.6	18.7	365	59.1	6826

*SA is value from direct calculation (Table 4.3)

Table 4.19 The heavy metal concentrations and DAevent at mean and RME for workers in Ngooleum village, Roi Et province, Thailand

	Elements	Concentration (mg/kg)		DAevent* (mg/cm^2/event)	
		Mean	RME	Mean	RME
Male	Ba	12.62	NC	1.26×10^{-8}	NC
(n=5)	Cd	1.2	NC	1.20×10^{-10}	NC
	Cr	3.36	NC	3.36×10^{-9}	NC
	Mn	7.81	NC	7.81×10^{-9}	NC
	Ni	8.63	NC	8.63×10^{-9}	NC

	Elements	Concentration (mg/kg)		DAevent* (mg/cm^2/event)	
		Mean	**RME**	**Mean**	**RME**
	Pb	4.1	NC	4.10 x10^{-9}	NC
Female (n=30)	Ba	10.76	14.30	1.08 x10^{-8}	4.29 x10^{-8}
	Cd	1.12	1.45	1.12 x10^{-10}	4.35 x10^{-10}
	Cr	2.67	4.22	2.67 x10^{-9}	1.27 x10^{-8}
	Mn	6.93	9.76	6.93 x10^{-9}	2.93 x10^{-8}
	Ni	8.13	12.13	8.13 x10^{-9}	3.64 x10^{-8}
	Pb	3.46	6.21	3.46 x10^{-9}	1.86 x10^{-8}
Total (n=35)	Ba	11.03	14.25	1.10 x10^{-8}	4.27 x10^{-8}
	Cd	1.13	1.48	1.13 x10^{-10}	4.43 x10^{-10}
	Cr	2.77	4.45	2.77 x10^{-9}	1.34 x10^{-8}
	Mn	7.06	9.73	7.06 x10^{-9}	2.92 x10^{-8}
	Ni	8.2	12.34	8.20 x10^{-9}	3.70 x10^{-8}
	Pb	3.55	6.51	3.55 x10^{-9}	1.95 x10^{-8}

*DAevent is value from direct calculation of DAevent formula in chapter 2 (US EPA, 2004)

NC is not calculation (a small number of male (n=5) could not computed by spss)

In Table 4.20 showed the average dermal absorb dose (DAD) of male workers of Ba, Cd, Cr, Mn, Ni, and Pb were 2.77 x10^{-7} mg/kg, 2.64 x10^{-9} mg/kg, 7.38 x10^{-8} mg/kg, 1.71 x10^{-7} mg/kg, 1.89 x10^{-7} mg/kg, and 8.98 x10^{-8} mg/kg, respectively and female were 2.58 x10^{-7} mg/kg, 2.68 x10^{-9} mg/kg, 6.39 x10^{-8} mg/kg, 1.66 x10^{-7} mg/kg, 1.95 x10^{-7} mg/kg, and 8.28 x10^{-8} mg/kg, respectively. If consider all of thirty-five incense workers in total group, the average concentration of Ba, Cd, Cr, Mn, Ni, and Pb were similar to male and female were 2.58 x10^{-7} mg/kg, 2.64 x10^{-9} mg/kg, 2.64 x10^{-9} mg/kg, 1.65 x10^{-7} mg/kg, 1.92 x10^{-7} mg/kg, and 8.30 x10^{-8} mg/kg, respectively. At 95th percentile, the dermal absorb dose (DAD) of Ba, Cd, Cr, Mn, Ni, and Pb for female workers were 1.02 x10^{-6} mg/kg, 1.06 x10^{-8} mg/kg, 3.20 x10^{-7} mg/kg, 7.00 x10^{-7} mg/kg, 8.87 x10^{-7} mg/kg, and 4.68 x10^{-7} mg/kg, respectively. For total workers, the DAD at 95th percentile of Ba, Cd, Cr, Mn, Ni, and Pb were 1.00 x10^{-6} mg/kg, 1.04 x10^{-8} mg/kg, 3.12 x10^{-7} mg/kg, 6.83 x10^{-7} mg/kg, 8.66 x10^{-7} mg/kg, and 4.57 x10^{-7} mg/kg, respectively.

To get hazard quotient (HQ), had to compare dermal absorb dose (DAD) with dermal reference dose (RfD_d) in equation 2.5. The hazard quotients (HQ) were calculated all of heavy metals at the average and 95th percentile (see in Table 4.19). From the calculation found that the HQ values of each group were below one (Table 4.20). Male workers got HQ values at the average of Ba, Cd, Cr, Mn, Ni, and Pb were 5.64 x10^{-5}, 2.20 x10^{-4}, 4.92 x10^{-3}, 2.85 x10^{-4}, 9.46 x10^{-4}, and 2.14 x10^{-4}, respectively (Table 4.19 and Figure4.5).

In the case study, female workers got HQ values at average more than male workers, so these Ba, Cd, Cr, Mn, Ni, and Pb were 5.26 x10^{-5}, 2.24 x10^{-4}, 4.26 x10^{-3}, 2.77 x10^{-4}, 9.74 x10^{-4}, and 1.97 x10^{-4}, respectively. The HQ values of Ba, Cd, Cr, Mn, Ni, and Pb for female at 95th percentile were 2.09 x10^{-4}, 8.68 x10^{-4}, 2.02 x10^{-2}, 1.17 x10^{-3}, 4.36 x10^{-3}, and 1.06 x10^{-3}, respectively (Table 4.20 and Figure 4.6). The last HQ values at average and 95th percentile of Ba, Cd, Cr, Mn, Ni, and Pb were calculated in term of total workers as 5.26 x10^{-5}, 2.20 x10^{-4}, 4.32 x10^{-3}, 2.75 x10^{-4}, 9.59 x10^{-4}, and 1.98 x10^{-4}, respectively and 2.04 x10^{-4}, 8.64 x10^{-4}, 2.08 x10^{-2}, 1.14 x10^{-3}, 4.33 x10^{-3}, and 1.09 x10^{-3}, respectively (Table 4.20 and Figure 4.7).

Hazard index (HI) value is summation of HQ values that come from many routes or many chemical agents. The study concerned the six heavy metals, thus the HQ values of the heavy metals were combined together as hazard index (HI) in equation 2.6. If HI values equal or more than one ($HI \geq 1$), that means the non-carcinogenic risk is concerned but below one that means the risk from non-carcinogenic is not concerned. The calculations of HI values at average and 95th percentile were shown in table 4.19 and Figure 4.8. For male, female, and total workers, the HI values at average were 5.65 x10^{-3}, 5.99 x10^{-3}, and 6.02 x10^{-3}, respectively. At 95th percentile, the HI values of female, and total were 2.79 x10^{-2}, and 2.84 x10^{-2}, respectively.

In conclusion, both HQ for each heavy metal and HI values for the six heavy metals of male, female, and total workers at average and 95th percentile were below one. Thus, there were no the non-carcinogenic risk from these heavy metals via dermal route.

Because lack of researches in risk assessment of heavy metal via dermal exposure in incense workers, the researches that were shown involving risk assessment of heavy metals via dermal route in contaminated mine and soil. The previous study of human health risk assessment case study an abandoned metal smelter site in Poland studied the risk from heavy metals; so dermal route was one of the routes that this case concerned. This study was interested in cadmium (Cd), copper (Cu), iron (Fe), manganese (Mn), lead (Pb), and zinc (Zn) of industrial scenario (I) and recreational scenario (II). The dermal risk of Cd, Cu, Fe, Mn, Pb, and Zn for industrial scenario (I) were 1.5, 1.3 $x10^{-3}$, 5.3 $x10^{-3}$, 1.5 $x10^{-3}$, not calculated, and 1.2 $x10^{-3}$, respectively. For recreational scenario (II), the dermal risk of Cd, Cu, Fe, Mn, Pb, and Zn were 6.0 $x10^{-1}$, 5.0 $x10^{-4}$, 2.1 $x10^{-3}$, 5.9 $x10^{-4}$, not calculated, and 5.0 $x10^{-3}$, respectively. If summation the risk in the scenario I and II, the HI values were 1.5 and 6.0 $x10^{-1}$, respectively. Thus, the non-carcinogenic risk via dermal route was concerned only industrial scenario (Wcislo *et al*., 2002). Moreover, in Taiwan, Hung et al. studied health risk-based assessment and management of heavy metals contaminated soil site (Hey *et al*., 2010). Four heavy metals as Zn, Cr, Cu, and Ni were measured the concentration and calculated the risk from dermal contact. The average HQ value of Zn, Cr, Cu, and Ni were 4.7 $x10^{-5}$, 1.1 $x10^{-5}$, 1.2 $x10^{-5}$, and 3.0 $x10^{-5}$, respectively. The maximum value of of Zn, Cr, Cu, and Ni were 8.9 $x10^{-5}$, 2.8 $x10^{-5}$, 1.6 $x10^{-5}$, and 5.6 $x10^{-5}$, respectively. Although calculated the risk in term of estimation maximum or summation of all elements, the results still below one. Thus, there were not concerned the non-carcinogenic risk via dermal contact to soil. To sum up, indirect exposure of heavy metal rarely occurred risk.

Table 4.20 Health risk assessment of heavy metals due to hand wipe samples of male workers in Ngooleum village, RoiEt province, Thailand

	Elements	DAD		RfD_d [a]	HQ		HI	
		Mean	RME		Mean	RME	Mean	RME
Male	Ba	2.77×10^{-7}	NC	4.90×10^{-3}	5.64×10^{-5}	NC	5.65×10^{-3}	NC
	Cd	2.64×10^{-9}	NC	1.20×10^{-5}	2.20×10^{-4}	NC		
	Cr	7.38×10^{-8}	NC	1.50×10^{-5}	4.92×10^{-3}	NC		
	Mn	1.71×10^{-7}	NC	6.00×10^{-4}	2.85×10^{-4}	NC		
	Ni	1.89×10^{-7}	NC	2.00×10^{-4}	9.46×10^{-4}	NC		
	Pb	8.98×10^{-8}	NC	4.20×10^{-4}	2.14×10^{-4}	NC		
Female	Ba	2.58×10^{-7}	1.02×10^{-6}	4.90×10^{-3}	5.26×10^{-5}	2.09×10^{-4}	5.99×10^{-3}	2.79×10^{-2}
	Cd	2.68×10^{-9}	1.06×10^{-8}	1.20×10^{-5}	2.24×10^{-4}	8.68×10^{-4}		
	Cr	6.39×10^{-8}	3.20×10^{-7}	1.50×10^{-5}	4.26×10^{-3}	2.02×10^{-2}		
	Mn	1.66×10^{-7}	7.00×10^{-7}	6.00×10^{-4}	2.77×10^{-4}	1.17×10^{-3}		
	Ni	1.95×10^{-7}	8.87×10^{-7}	2.00×10^{-4}	9.74×10^{-4}	4.36×10^{-3}		
	Pb	8.28×10^{-8}	4.68×10^{-7}	4.20×10^{-4}	1.97×10^{-4}	1.06×10^{-3}		
Total	Ba	2.58×10^{-7}	1.00×10^{-6}	4.90×10^{-3}	5.26×10^{-5}	2.04×10^{-4}	6.02×10^{-3}	2.84×10^{-2}
	Cd	2.64×10^{-9}	1.04×10^{-8}	1.20×10^{-5}	2.20×10^{-4}	8.64×10^{-4}		
	Cr	6.48×10^{-8}	3.12×10^{-7}	1.50×10^{-5}	4.32×10^{-3}	2.08×10^{-2}		
	Mn	1.65×10^{-7}	6.83×10^{-7}	6.00×10^{-4}	2.75×10^{-4}	1.14×10^{-3}		
	Ni	1.92×10^{-7}	8.66×10^{-7}	2.00×10^{-4}	9.59×10^{-4}	4.33×10^{-3}		
	Pb	8.30×10^{-8}	4.57×10^{-7}	4.20×10^{-4}	1.98×10^{-4}	1.09×10^{-3}		

[a] Dermal reference dose (RfD_d) default value (chapter 2)

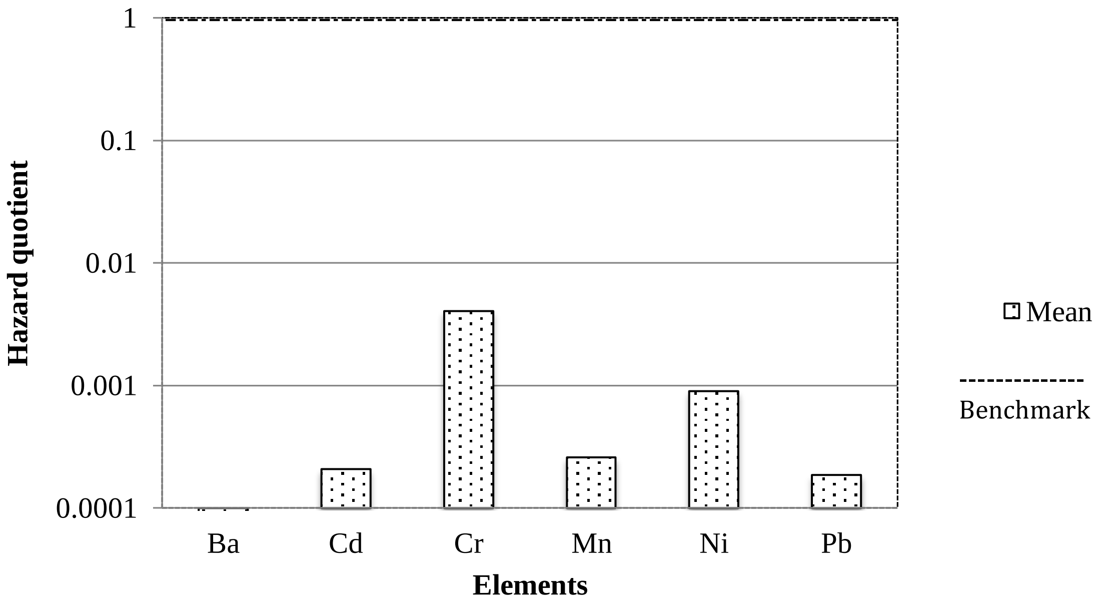


Figure 4.5 Hazard quotient (HQ) of each heavy metal at mean by male workers (n=5) in Ngooleum village, Roi Et province, Thailand

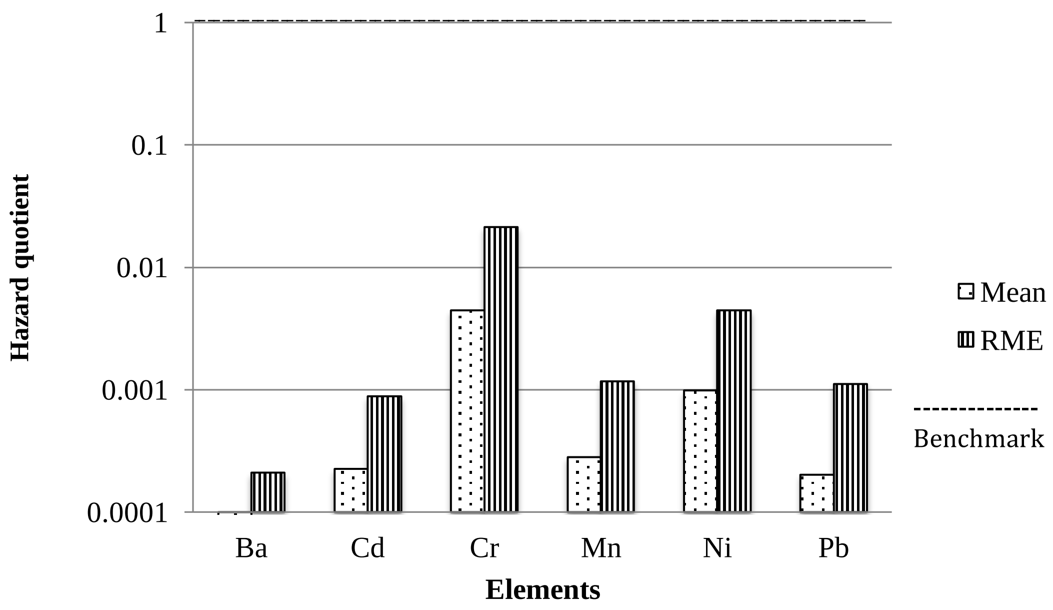


Figure 4.6 Hazard quotient (HQ) of each heavy metal at mean and 95th percentile level by female workers (n=30) in Ngooleum village, Roi Et province, Thailand

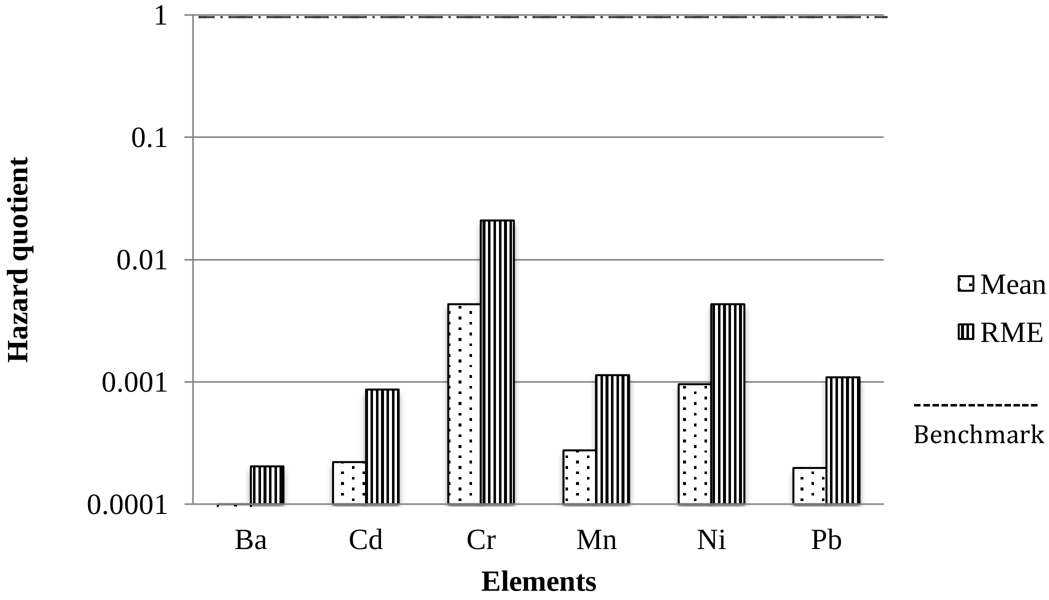


Figure 4.7 Hazard quotient (HQ) of each heavy metal at mean and 95th percentile level by total workers (n=35) in Ngooleum village, Roi Et province, Thailand

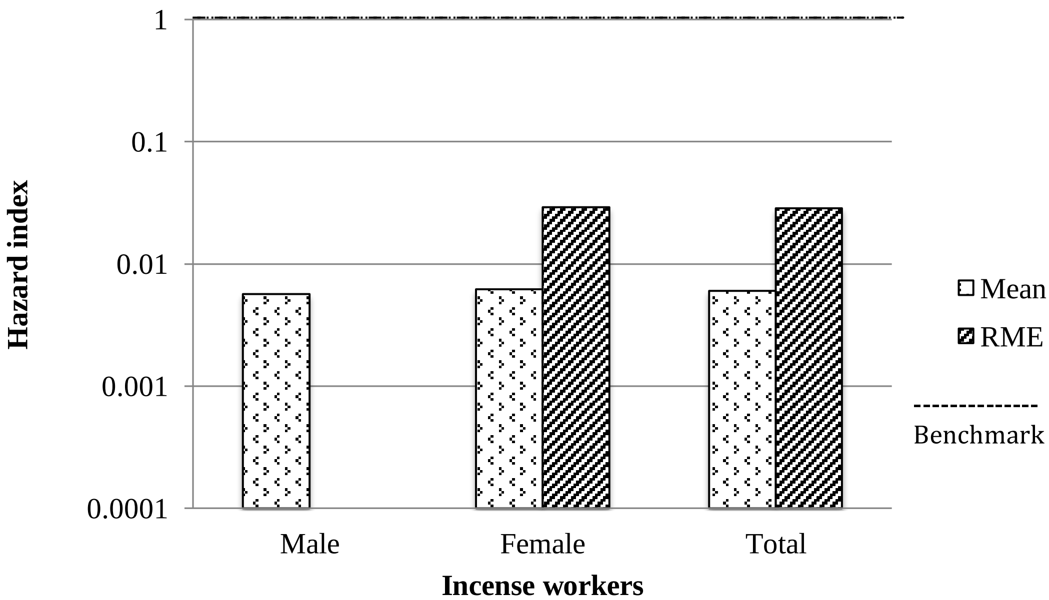


Figure 4.8 Hazard index (HI) at mean and 95th percentile level by male, female, and total workers in Ngooleum village, Roi Et province, Thailand

4.7 Subjective health and symptoms

General health symptoms in the questionnaire that were used to ask participant, what are their health symptoms and what are general health symptoms that participants ever have? Although almost participants had nothing in general health, but each allergy, migraine, gastritis, hypertension, liver disease, kidney disease, and lymph node cancer were found in participants 1-3% of total participants. Hand eczema, skin rash, cramp, vomit, sweat, inconvenient breathing, headache are general health symptoms that can occur when workers expose heavy metals, so that found always in sweat and headache were 10% and 1% of total participant respectively. Participants were found rarely and nothing in hand eczema, skin rash, cramp, vomit, sweat, inconvenient breathing, and headache were 6% and 94%, 17% and 83%, 21% and 79%, 4% and 96%, 44% and 46%, 16% and 84%, and 23% and 76%, respectively. To sum up, the general health symptoms are effects from any route that expose to heavy metals but there are a little data of health symptoms from heavy metals (ATSDR, 1999), (ATSDR: Barium and barium compound, 2005), (ATSDR, 2005b), (WHO, 1981, 1999a). The HI values of heavy metal in this study below one meant this study had low probability or no chance to get the risk. Thus, the participants occurred rarely in the health symptoms (see in Table 4.20).

Table 4.21 Subjective health and symptoms in Moo 12 of Ngooleum village in Roi Et province, Thailand

Characteristics	**Incense workers**					
	Male		**Female**		**Total**	
	(n=65)	**%**	**(n=35)**	**%**	**(n=100)**	**%**
Health symptoms						
Allergy	1	1.5	0	0	1	1
Migraine	0	0	3	8.6	3	3
Gastritis	2	3.1	0	0	2	2
Hypertension	0	0	1	2.9	1	1
Liver disease	2	3.1	0	0	2	2
Kidney disease	1	1.5	1	2.9	2	2
Nothing	59	90.8	29	82.9	88	88
Lymph node cancer	0	0	1	2.9	1	1
Symptoms from working						
Hand eczema						
Always	0	0	0	0	0	0
Rarely	2	3.1	4	11.4	6	6
Never	63	96.9	31	88.6	94	94
Skin rash						
Always	0	0	0	0	0	0
Rarely	8	12.3	9	25.7	17	17
Never	57	87.7	26	74.3	83	83
Cramp						
Always	0	0	0	0	0	0
Rarely	10	15.4	11	31.4	21	21
Never	55	84.6	24	68.6	79	79

Characteristics	Incense workers					
	Male		Female		Total	
	(n=65)	%	(n=35)	%	(n=100)	%
Vomit						
Always	0	0	0	0	0	0
Rarely	2	3.1	2	5.7	4	4
Never	63	96.9	33	94.3	96	96
Sweat						
Always	8	12.3	2	5.7	10	10
Rarely	31	47.7	13	37.1	44	44
Never	26	40.0	20	57.1	46	46
Inconvenient breathing						
Always	0	0	0	0	0	0
Rarely	14	21.5	2	5.7	16	16
Never	51	78.5	33	94.3	84	84
Headache						
Always	0	0	1	2.9	1	1
Rarely	9	13.8	14	40.0	23	23
Never	56	86.2	20	57.1	76	76

4.8 The relationship between quantitative risk assessment and risk matrix

Risk matrix in qualitative risk assessment was weighted the score in the vertical axis as time working frequency (hr/week) in Table 2.2, so the score of this study in the axial was 3 (28-42 hr). The horizontal axis showed level consequence symptom and the score of this study was 2 (workers had skin rash) in Table 2.3. Thus the score of the risk matrix was 6 as medium-medium that meant incense workers in this case were the medium priority in the risk management case. The effect is medium, so they should to know the information about heavy metal and should be concerned during planning and risk assessment. So this study should be quantified the risk assessment and when calculated the HQ and HI values of heavy metals were below one. Although quantitative risk assessment had no non-carcinogenic risk, it was a potential and in the future may be occur the risk via dermal contact.

4.9 Human health risk management

From the heavy metal concentrations of after working and after washing hands, the results of Wilcoxson test showed statistically significant difference (in Table 4.14). Thus this study was recommended to wash hands for reducing heavy metal concentration on hands. Table 4.16 showed the comparison for heavy metal concentrations of after working by non-using glove and using gloves. The result found the mean heavy metal concentration of two events was statistically significant, so glove using was recommended to protect hands for heavy metal exposure.

4.5.1 Hand washing

When incense workers finish working at lunch and dinner, they always washing hands by water, soap, and dishwashing liquid (Table4.4) but may be wrong in hygienic practice. The steps of hand washing firstly wash hands with water and use soap to rub hands and fingers at least 15 seconds. Then rinse hands with water to remove soap and rub the hands surface and fingers for drying with a towel or tissue paper. Moreover, an alcohol-based hand gel or hand wiping with alcohol should be used to remove heavy metal dust on hands (Duggan, 1985).

4.5.2 Glove using

Because incense workers not use any cover their hands, glove using was recommend to incense workers for preventing the heavy metal via dermal contact from incense making process. When incense workers contact with dyeing color during working should be used rubber latex gloves. Before and after use gloves, hands should hygiene and clean follow hand-washing method. (Boyce and Pittet, 2002).

CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study investigated the human risk from heavy metals via dermal contact of incense workers in Ngooleum village, Roi Et province, Thailand. The results were concluded as following;

1. General information of participants was 65 male and 53 female participants. The main age of male, female and total participants were in the range of 31-40 years. The main weight of male and female in the range of 51-60 kg and female was 61-70 kg. The main height of male in the range of 161-170 cm and female was 151-160 cm. The almost education level of participants were elementary school. The main occupations of total participants were incense worker and farmer.

2. For participant and duty in workplace process, the main duties for male were the bamboo preparation, incense powder mixing, and color dipping and dying. Female participants always work mainly in incense packing. The working duration of male participants was less than 11 years, but female participants was in the range of 11-20 years. Half of male participants worked 2 events per day or around 3.5-6 hr, but female participants worked nearly of 1 or 2 events or more than 6 hr.

3. For personal protective equipment (PPE) and self-cleaning, all participants had dyeing color left on their hands and did not using gloves when working. For one day, participants always washed hands 3-4 times and used water, soap, and dishwashing liquid.

4. The direct average value of hand surface area of male (n=5) and female (n=30) were 0.091 and 0.080 m^2.

5. The average concentration (±SD) of Ba, Cd, Cr, Mn, Ni, and Pb in dissolved dye were 1.47 ± 0.21 mg/kg, 0.16 ± 0.01 mg/kg, 1.34 ± 0.13 mg/kg, 1.12 ± 0.10 mg/kg, 0.64 ± 0.08 mg/kg, 0.90 ± 0.05 mg/kg, respectively. The average concentration (±SD) of Ba, Cd, Cr, Mn, Ni, and Pb in incense stick were 1.30 ± 0.29 mg/kg, 0.08 ± 0.03 mg/kg, 0.89 ± 0.10 mg/kg, 0.87 ± 0.13 mg/kg, 0.99 ± 0.19 mg/kg, 0.27 ± 0.05 mg/kg, respectively. The average residue concentrations (±SD) of Ba, Cd, Cr, Mn, Ni, and Pb on worker's hands were 11.03±2.31 mg/kg, 1.13±0.23 mg/kg,

2.77±0.83 mg/kg, 7.06±1.92 mg/kg, 8.20±2.22 mg/kg, and 3.55±1.32 mg/kg, respectively

6. The mean difference of dissolved dye, incense stick, and hand wiping sample was statistically significant. Paired between dissolved dye or incense stick and hand wiping sample were statistically significant. However, the mean difference of Ba, Mn, and Ni of paired between dissolved dye and incense stick were not statistically significant , but Cd, Cr, and Pb were statistically significant.

7. Willcoxson test for compared mean difference of heavy metal concentration at different times. There were four paired samples as before working-after working, after working-after washing hands, before working-after washing hands, and after working by non-using gloves and using gloves. So all of paired samples were statistically significant.

8. The average dermal absorb dose (DAD) of thirty-five incense workers in total group, the average concentration of Ba, Cd, Cr, Mn, Ni, and Pb were 2.58 $x10^{-7}$ mg/kg-day, 2.64 $x10^{-9}$ mg/kg-day, 2.64 $x10^{-9}$ mg/kg-day, 1.65 $x10^{-7}$ mg/kg-day, 1.92 $x10^{-7}$ mg/kg-day, and 8.30 $x10^{-8}$ mg/kg-day, respectively. At 95th percentile, the dermal absorb dose (DAD) of Ba, Cd, Cr, Mn, Ni, and Pb for total workers, the DAD at 95th percentile of Ba, Cd, Cr, Mn, Ni, and Pb were 1.00 $x10^{-6}$ mg/kg-day, 1.04 $x10^{-8}$ mg/kg-day, 3.12 $x10^{-7}$ mg/kg-day, 6.83 $x10^{-7}$ mg/kg-day, 8.66 $x10^{-7}$ mg/kg-day, and 4.57 $x10^{-7}$ mg/kg-day, respectively.

9. The HQ values at average and 95th percentile of Ba, Cd, Cr, Mn, Ni, and Pb were calculated in term of total workers as 5.26 $x10^{-5}$, 2.20 $x10^{-4}$, 4.32 $x10^{-3}$, 2.75 $x10^{-4}$, 9.59 $x10^{-4}$, and 1.98 $x10^{-4}$, respectively and 2.04 $x10^{-4}$, 8.64 $x10^{-4}$, 2.08 $x10^{-2}$, 1.14 $x10^{-3}$, 4.33 $x10^{-3}$, and 1.09 $x10^{-3}$, respectively

10. For male, female, and total workers, the HI values at average were 5.65 $x10^{-3}$, 5.99 $x10^{-3}$, and 6.02 $x10^{-3}$, respectively. At 95th percentile, the HI values of female, and total were 2.79 $x10^{-2}$, and 2.84 $x10^{-2}$, respectively.

11. Both HQ for each heavy metal and HI values for the six heavy metals of male, female, and total workers at average and 95th percentile were below one. Thus, there were no the non-carcinogenic risk from these heavy metals via dermal route.

12.General subjective health symptoms of participants was found rarely in allergy, migraine, gastritis, hypertension, liver disease, kidney disease, and lymph node cancer. For symptoms to expose heavy metal, participant had nothing or rarely found in skin rash, cramp, vomit, sweat, inconvenient breathing, and headache.

5.2 Recommendations

1. Although the risk of heavy metal in incense stick for Ngooleum village, Roi Et province, Thailand was not concerned in non-carcinogenic effect via dermal contact, the risk from carcinogenic may be presented in the future if have data to support.

2. Incense workers may be occurred the risk from contact incense stick, if they work for along time or expose at high concentration. Thus, glove using and hand washing were recommended to incense workers and the leader of the village should encourage incense workers in the practice.

3. The research studied only Moo 12 of Ngooleum village, Roi Et province, Thailand, but in other villages or different areas that lack of self-cleaning and protecting regulations should consider in adverse health effect from dermal contact to dyeing color too. For risk management, hand washing when workers finished incense working and gloves using during working should be advised to workers.

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APPENDIX A

Interviewer name _______________ **Questionnaire no.___________**

Date ______/_______/_____

Center of Excellence for

Environmental and Hazardous Waste Management

Chulalongkorn University

Questionnaire for Human Risk Assessment of Incense Workers at Ngooleum village, Dongdang subdistrict, Chaturaphakpman district, Roi Et province, Thailand.

Please answer the question or mark X in the ( ) and fill in the blank.

Part I: General information

1.Name____

2.Address____

____

3.Gender ( ) Male ( ) Female

4. Married Status ( ) Single ( ) Married

( ) Widow/Widower ( ) Divorce/Separate

5. What is your education Background?

( ) Illiteracy ( ) Elementary school

( ) Junior high school or vocational certificate

( ) Senior high school or high vocational certificate

( ) Diploma ( ) Bachelor's degree, or above

6. How many members in your family?

( ) 1-2 ( ) 3-5 ( ) more than 5

7. Age_________________years

8. Body weight__________________kg

9. Height______________________cm

10. Hand surface area______________cm^2

Part II: Working information

11. What is/are your occupation(s)? (You can choose more than one choice)

( ) Incense worker ( ) Agriculture/ Farmer

( ) General employee ( ) Merchant

( ) Others__________________

12. How many day/days do you working incense process per week?

( ) 1-2 ( ) 3-4 ( ) 5-7

13. How many years do you work on incense working?

( ) 1-3 ( ) 4-6

( ) 7-10 ( ) above 10

14. How many times do you working incense process per day?

( ) 1 ( ) 2 ( ) 3

15. How many hours do you work incense process per day?

( ) 1-3 ( ) 3.5-6 ( ) above 6

16. What is/are your duty(s) in incense making process? (You can choose more than one choice)

( ) Bamboo preparation ( ) Incense powder mixing

( ) Incense molding ( ) Color dipping and drying

( ) Perfume spraying ( ) Incense packing

17. Do you involve to contact dyeing color?

( ) Contact ( ) Not contact

18. Do you have dyeing color left on your body?

( ) Yes ( ) No

19. How many times do you wash or clean hands per day?

( ) Nothing ( ) 1-2 ( ) 3-4

20. What type of detergent do you use to wash your hands?

( ) Water ( ) Soap

( ) Powdered detergent ( ) Dishwashing liquid

21. Do you use gloves when working?

( ) Use (end of the interview) ( ) Not use (go to question 22)

Part III: General health information

22. What is/are your health symptom(s)? (You can choose more than one choice)

( ) Allergy ( ) Migraine

( ) Gastritis ( ) Hypertension

( ) Liver disease ( ) Kidney disease

( ) Others_________

23. Have you ever allergy in medicine?

( ) No ( ) Yes (name:________________)

24. During the last 12 months, do you have sign or symptom following the table or not while and/or working?

Symptoms	Always	Sometime	Never
Hand eczema			
Skin rash			
Cramp			
Vomit			
Sweat			
Inconvenient breathing			
Headache			

Adopt from: Taneepanichskul, 2009 and Siripanich, 2010.

แบบสอบถามการรับสัมผัสผ่านทางผิวหนังของคนงานผลิตธูป

ชื่อผู้สัมภาษณ์ ______________________________ แบบสอบถาม

เลขที่__________ วันที่ _____/______/_____

ศูนย์ความเป็นเลิศแห่งชาติด้านการจัดการ

สิ่งแวดล้อมและของเสียอันตราย

แบบสอบถามสำหรับการประเมินความเสี่ยงสุขภาพของคนงาน ที่ผลิตธูปหมู่บ้านงูเหลือม ต.ดงแดง อ.จตุรพักตรมาน จังหวัดร้อยเอ็ด ประเทศไทย

กรุณาตอบคำถามและทำเครื่องหมาย X ใน ( ) และเติมลงในช่องว่าง

ส่วนที่ 1: ข้อมูลทั่วไปเกี่ยวกับผู้ตอบแบบสอบถาม

1.ชื่อ-นามสกุล____

2.ที่อยู่____

____

3.เพศ	( )	ชาย	( )	หญิง
4. สถานภาพ	( )	โสด	( )	แต่งงาน
	( )	หม้าย	( )	หย่าร้าง

5. วุฒิการศึกษาสูงสุด

( )	ไม่ได้เรียนหนังสือ	( )	ประถมศึกษา
( )	มัธยมศึกษาตอนต้น หรือ ปวช.	( )	มัธยมศึกษาตอนปลาย หรือ ปวส.
( )	อนุปริญญา	( )	ปริญญาตรีหรือสูงกว่า

6. จำนวนสมาชิกในครอบครัว

( ) 1-2 ( ) 3-5 ( ) *มากกว่า 5*

7. อายุ________________ปี

8. น้ำหนัก________________กิโลกรัม

9. ส่วนสูง______________________เซนติเมตร

10. พื้นที่ผิวของมือ_____________ซม^2

ส่วนที่ 2 : ข้อมูลการทำงาน

11. อาชีพ (สามารถเลือกได้มากกว่า 1 ข้อ)

( ) ผลิตธูป ( ) เกษตกร/ชาวนา

( ) รับจ้างทั่วไป ( ) ค้าขาย

( ) อื่นๆ_________________

12. จำนวนวันที่ท่านทำงานในการผลิตธูป?

( ) 1-2 วัน/สัปดาห์ ( ) 3-4 วัน/สัปดาห์ ( ) 5-7 วัน/สัปดาห์

13. ระยะเวลาที่ท่านทำงานในการผลิตธูป

( ) 1-3 ปี ( ) 4-6 ปี

( ) 7-10 ปี ( ) มากกว่า 10 ปี

14. จำนวนครั้งที่ทำงานภายใน 1 วัน?

( ) 1 ครั้ง ( ) 2 ครั้ง ( ) 3 ครั้ง

15. จำนวนชั่วโมงในการทำงานใน 1 วัน?

( ) 1-3 *ชั่วโมง* ( ) 3.5-6 *ชั่วโมง* ( ) *มากกว่า* 6 *ชั่วโมง*

16. หน้าที่ของท่านในกระบวนการผลิตธูป? (สามารถเลือกได้มากกว่า 1 ข้อ)

( ) การเตรียมไม้ไผ่ ( ) การผสมผงธูป

( ) การโม่ธูป ( ) การชุบสีและย้อมสี

( ) การฉีดน้ำหอม ( ) บรรจุหีบห่อธูป

17. ท่านได้สัมผัสสีย้อมหรือไม่?

( ) *สัมผัส* ( ) *ไม่สัมผัส*

18. สีย้อมได้ติดอยู่ที่ร่างการท่านหรือไม่?

( ) ใช่ (ระบุ______) ( ) ไม่

19. จำนวนครั้งที่ท่านล้างมือ?

( ) ไม่ได้ล้าง ( ) 1-2 ครั้งต่อวัน ( ) 3-4 ครั้งต่อวัน

20. สิ่งที่ท่านใช้ล้างมือ?

( ) น้ำ ( ) สบู่

( ) ผงซักฟอก ( ) น้ำยาล้างจาน

21. ท่านได้สวมใส่ถุงมือเวลาทำงานหรือไม่?

( ) ใช้ (จบการสัมภาษณ์) (ไปที่ข้อ 22) ( ) ไม่ใช้ (ไปที่ข้อ 22)

ส่วนที่ 3 : ข้อมูลสุขภาพทั่วไป

22. โรคประจำตัวของท่าน? (สามารถเลือกได้มากกว่า 1 ข้อ)

( ) ภูมิแพ้ ( ) ไมเกรน

( ) กระเพราะอักเสบ ( ) ความดันโลหิตสูง

( ) โรคตับ ( ) โรคไต

( ) อื่นๆ_________

23. ท่านแพ้ยาหรือไม่?

( ) ไม่ ( ) ใช่ (โปรดระบุ:_______________)

24. ใน 12 เดือนที่ผ่านมาในขณะการทำงานหรือหลังการทำงานท่านได้มีการแสดงอาการตามตารางหรือไม่?

อาการ	บ่อยๆ	บางครั้ง	ไม่เคย
ผื่นแดงที่มือ			
คันที่ผิวหนัง			
ตะคริว			
อาเจียน			
เหงื่อออก			
การหายใจติดขัด			
ปวดหัว			

APPENDIX B

Limit of Detection (LOD) and Limit of Quantitation (LOQ)

In the analysis of trace elements, a low concentration of analyzes is a correctly trend. The methods or instrument, which is selected, need the information about lower limit of detection (LLD) or limit of detection (LOD), method detection limit (MDL). LOD is lowest concentration level that can be determined or detected with sufficient confidence. LOD is defined as the concentration of the analyze giving a signal equal to the blank plus 3 and plus the standard deviation of the blank. The blank is omitted because in the calculation of analytical give the blank is zero. The LOD can be calculated by the equation below (van Reeuwijk, Guidelines for Quality Management in Soil and Plant Laboratories):

$$\text{LOD} = 3 \text{ x } s_{bl}$$ *Equation B_1*

The limit is 93% confidence that the signal is not caused the blank but that the method is detected the evidence of analysis. The equation uses in any limit and some case that has 7% uncertainty. If the analysis has 5% uncertainty, the LOD = 3.3 x S_{bl}. However, the limit of quantitation (LOQ) is considered when the precision in that concentration range is often relatively determination. The LOQ is the double of LOQ (LOQ = 2 x LOD) or :

$$\text{LOQ} = 6 \times s_{bl}$$ *Equation $B_{2.1}$*

or sometime as :

$$\text{LOQ} = 10 \times s_{bl}$$ *Equation $B_{2.2}$*

Selecting equation $B_{2.1}$ or $B_{2.2}$ need to know the mean of the blanks and the corresponding standard deviation. The s_{bl} can be gained by running a statistically sufficient number of blank determinations (usually a minimum of 10, and not excluding outliers). These equations are used to assess noise that is defined as the difference between the maximum and minimum values of the signal in the absence of the analyze which is measured during in two minutes.

Assessment of method precision

The precision is expressed by the absolute value of the relative standard deviation *(RSD)* or coefficient of variation *(CV)* that used to estimate the precision of multiple samples. The precision is calculated from equations below:

$$\% \text{ Percision} = \frac{SD \times 100}{\text{Mean}}$$

Equation B_3

Assessment of method accuracy

The accuracy of method usually uses percent recovery to assess an analysis. The percent recovery can be expressed as an absolute value by:

$$\% \text{ Recovery} = \frac{Ms - Mu}{Ts}$$

Equation B_4

Table B-1 Data input of dissolved dye, incense stick, and gauze pad at low spike concentration

Dissolved dye	Spike (mg/kg)	Unspike (mg/kg)	Spike add (mg/kg)	Recovery	Mean	SD	RSD
Ba	1.78	1.10	0.76	89.2	1.78	0.10	5.63
Cd	0.75	0.15	0.74	80.5	0.75	0.04	5.50
Cr	1.14	0.38	0.78	98.0	1.14	0.11	9.34
Mn	1.36	1.05	0.38	81.4	1.36	0.05	4.04
Ni	0.91	0.26	0.70	93.8	0.91	0.06	6.27
Pb	1.28	0.66	0.64	96.0	1.28	0.06	4.83
Incense							
Ba	1.66	1.19	0.40	117.9	1.66	0.07	4.08
Cd	0.89	0.15	0.88	84.3	0.89	0.05	5.23
Cr	1.76	0.65	1.00	110.6	1.76	0.11	6.18
Mn	1.79	1.45	0.40	84.4	1.79	0.16	9.01
Ni	1.21	0.84	0.40	92.4	1.21	0.09	7.85
Pb	1.93	1.47	0.40	115.2	1.93	0.12	6.14
Gloze							
Ba	1.54	0.30	1.05	118.1	1.54	0.14	8.94
Cd	0.88	0.01	1.06	82.2	0.88	0.08	8.70
Cr	0.99	0.13	1.06	81.3	0.99	0.07	7.07
Mn	1.33	0.13	1.25	96.6	1.33	0.07	5.39
Ni	1.15	0.19	0.99	96.7	1.15	0.09	8.01
Pb	1.10	0.10	1.06	94.4	1.10	0.08	7.64

Table B-2 Data input of dissolved dye, incense stick, and gauze pad at high spike concentration

Dissolved dye	Spike (mg/kg)	Unspike (mg/kg)	Spike add (mg/kg)	Recovery	Mean	SD	RSD
Ba	4.66	1.60	3.41	89.62	4.66	0.35	7.56
Cd	3.87	0.17	3.94	93.97	3.87	0.15	3.81
Cr	3.88	0.38	3.85	91.08	3.88	0.28	7.19
Mn	3.93	1.05	3.58	80.48	3.93	0.19	4.86
Ni	3.39	0.26	3.90	80.36	3.39	0.21	6.09
Pb	4.05	0.59	3.74	92.57	4.05	0.25	6.21
Incense							
Ba	5.43	1.19	5.00	84.72	5.43	0.30	5.57
Cd	4.27	0.15	5.00	82.48	4.27	0.27	6.42
Cr	4.87	0.65	5.00	84.36	4.87	0.31	6.32
Mn	5.50	1.45	5.00	80.98	5.50	0.44	8.08
Ni	5.43	0.84	5.00	91.75	5.43	0.46	8.40
Pb	5.58	1.47	5.00	82.28	5.58	0.27	4.91
Gloze							
Ba	5.03	0.30	5.00	94.61	5.03	0.33	6.65
Cd	4.89	0.01	5.00	97.58	4.89	0.29	5.89
Cr	4.54	0.13	5.00	88.24	4.54	0.29	6.49
Mn	5.15	0.13	5.00	100.32	5.15	0.31	5.94
Ni	4.89	0.19	5.00	94.14	4.89	0.29	5.94
Pb	5.22	0.10	5.00	102.36	5.22	0.28	5.39

APPENDIX C

Table C-1 Individual risk assessment for male participants (n=5) of heavy metal due to incense dermal contact in Ngooleum village, Roi Et province, Thailand

	Elements	Individual exposure assessment											
		Cs*	**SA***	**EV***	**ED***	**EF***	**BW***	**AT***	**DAevent***	**DAD***	**RfD***	**HQ**	**HI**
1	Ba	14.09	814.2	2	30	365	51	10950	1.41 x10^{-8}	4.50 x10^{-7}	4.90 x10^{-3}	4.90 x10^{-5}	
	Cd	1.16	814.2	2	30	365	51	10950	1.16 x10^{-10}	3.72 x10^{-9}	1.20 x10^{-5}	1.20 x10^{-5}	
	Cr	2.27	814.2	2	30	365	51	10950	2.27 x10^{-9}	7.26 x10^{-8}	1.50 x10^{-5}	1.50 x10^{-5}	7.11 x10^{-3}
	Mn	8.42	814.2	2	30	365	51	10950	8.42 x10^{-9}	2.69 x10^{-7}	6.00 x10^{-4}	6.00 x10^{-4}	
	Ni	5.93	814.2	2	30	365	51	10950	5.93 x10^{-9}	1.89 x10^{-7}	2.00 x10^{-4}	2.00 x10^{-4}	
	Pb	6.25	814.2	2	30	365	51	10950	6.25 x10^{-9}	1.99 x10^{-7}	4.20 x10^{-4}	4.20 x10^{-4}	
2	Ba	12.64	888.2	1	20	365	62	7300	1.26 x10^{-8}	1.81 x10^{-7}	4.90 x10^{-3}	3.69E-05	
	Cd	1.55	888.2	1	20	365	62	7300	1.55 x10^{-10}	2.22 x10^{-9}	1.20 x10^{-5}	1.85E-04	
	Cr	4.43	888.2	1	20	365	62	7300	4.43 x10^{-9}	6.34 x10^{-8}	1.50 x10^{-5}	4.23E-03	5.80 x10^{-3}
	Mn	8.96	888.2	1	20	365	62	7300	8.96 x10^{-9}	1.28 x10^{-7}	6.00 x10^{-4}	2.14E-04	
	Ni	12.78	888.2	1	20	365	62	7300	1.28 x10^{-9}	1.83 x10^{-7}	2.00 x10^{-4}	9.16E-04	
	Pb	6.36	888.2	1	20	365	62	7300	6.36 x10^{-9}	9.11 x10^{-8}	4.20 x10^{-4}	2.17E-04	
3	Ba	11.37	844.6	2	20	365	55	7300	1.14 x10^{-8}	3.49 x10^{-7}	4.90 x10^{-3}	7.13E-05	
	Cd	0.97	844.6	2	20	365	55	7300	9.72 x10^{-11}	2.98 x10^{-9}	1.20 x10^{-5}	2.49E-04	
	Cr	2.70	844.6	2	20	365	55	7300	2.70 x10^{-9}	8.28 x10^{-8}	1.50 x10^{-5}	5.52E-03	7.45 x10^{-3}
	Mn	5.82	844.6	2	20	365	55	7300	5.82 x10^{-9}	1.79 x10^{-7}	6.00 x10^{-4}	2.98E-04	
	Ni	7.39	844.6	2	20	365	55	7300	7.39 x10^{-9}	2.27 x10^{-7}	2.00 x10^{-4}	1.14E-03	
	Pb	2.47	844.6	2	20	365	55	7300	2.47 x10^{-9}	7.60E-08	4.20 x10^{-4}	1.81E-04	
4	Ba	11.47	887.1	2	15	365	62	5475	1.15 x10^{-8}	3.28 x10^{-7}	4.90 x10^{-3}	6.70E-05	
	Cd	1.06	887.1	2	15	365	62	5475	1.06 x10^{-10}	3.03 x10^{-9}	1.20 x10^{-5}	2.52E-04	8.33 x10^{-3}
	Cr	3.27	887.1	2	15	365	62	5475	3.27 x10^{-9}	9.35 x10^{-8}	1.50 x10^{-5}	6.23E-03	

	Elements	Individual exposure assessment									RfD*	HQ	HI
		Cs*	SA*	EV*	ED*	EF*	BW*	AT*	DAevent*	DAD*			
	Mn	7.51	887.1	2	15	365	62	5475	7.51×10^{-9}	2.15×10^{-7}	6.00×10^{-4}	3.58E-04	
	Ni	8.72	887.1	2	15	365	62	5475	8.72×10^{-9}	2.49×10^{-7}	2.00×10^{-4}	1.25E-03	
	Pb	2.52	887.1	2	15	365	62	5475	2.52×10^{-9}	7.22×10^{-8}	4.20×10^{-4}	1.72E-04	
5	Ba	13.52	979.0	2	20	365	72	7300	1.35×10^{-8}	3.68×10^{-7}	4.90×10^{-3}	7.51E-05	9.61×10^{-3}
	Cd	1.28	979.0	2	20	365	72	7300	1.28×10^{-10}	3.49×10^{-9}	1.20×10^{-5}	2.91E-04	
	Cr	4.16	979.0	2	20	365	72	7300	4.16×10^{-9}	1.13×10^{-7}	1.50×10^{-5}	7.54E-03	
	Mn	8.34	979.0	2	20	365	72	7300	8.34×10^{-9}	2.27×10^{-7}	6.00×10^{-4}	3.78E-04	
	Ni	8.34	979.0	2	20	365	72	7300	8.34×10^{-9}	2.27×10^{-7}	2.00×10^{-4}	1.13E-03	
	Pb	2.88	979.0	2	20	365	72	7300	2.88×10^{-9}	7.84×10^{-8}	4.20×10^{-4}	1.87E-04	

* C (mg/kg)

*SA (cm)

*EV (event/day)

*EF (days/year)

*BW (kg)

*AT (days)

*DAevent (mg/cm^2/event)

*ADD (mg/kg-day)

*RfD (mg/kg-day)

Table C-2 Individual risk assessment for female participants (n=30) of heavy metal due to incense dermal contact in Ngooleum village, Roi Et province, Thailand

	Elements	Individual exposure assessment									RfD*	HQ	HI
		Cs*	SA*	EV*	ED*	EF*	BW*	AT*	DAevent*	DAD*			
1	Ba	13.53	687.6	2	25	365	40	9125	1.35×10^{-8}	4.65×10^{-7}	4.90×10^{-3}	9.49×10^{-5}	1.06×10^{-2}
	Cd	1.21	687.6	2	25	365	40	9125	1.21×10^{-10}	4.17×10^{-9}	1.20×10^{-5}	3.48×10^{-4}	
	Cr	3.56	687.6	2	25	365	40	9125	3.56×10^{-9}	1.23×10^{-7}	1.50×10^{-5}	8.17×10^{-3}	
	Mn	5.43	687.6	2	25	365	40	9125	5.43×10^{-9}	1.87×10^{-7}	6.00×10^{-4}	3.11×10^{-4}	
	Ni	8.15	687.6	2	25	365	40	9125	8.15×10^{-9}	2.80×10^{-7}	2.00×10^{-4}	1.40×10^{-3}	
	Pb	4.06	687.6	2	25	365	40	9125	4.06×10^{-9}	1.40×10^{-7}	4.20×10^{-4}	3.32×10^{-4}	
2	Ba	12.77	811.9	2	30	365	60	10950	1.28×10^{-8}	3.46×10^{-7}	4.90×10^{-3}	7.06×10^{-5}	5.50×10^{-3}
	Cd	1.37	811.9	2	30	365	60	10950	1.37×10^{-10}	3.72×10^{-9}	1.20×10^{-5}	3.10×10^{-4}	
	Cr	2.05	811.9	2	30	365	60	10950	2.05×10^{-9}	5.54×10^{-8}	1.50×10^{-5}	3.69×10^{-3}	
	Mn	8.54	811.9	2	30	365	60	10950	8.54×10^{-9}	2.31×10^{-7}	6.00×10^{-4}	3.85×10^{-4}	
	Ni	5.67	811.9	2	30	365	60	10950	5.67×10^{-9}	1.53×10^{-7}	2.00×10^{-4}	7.67×10^{-4}	
	Pb	4.28	811.9	2	30	365	60	10950	4.28×10^{-9}	1.16×10^{-7}	4.20×10^{-4}	2.76×10^{-4}	
3	Ba	9.23	817.4	3	30	365	61	10950	9.23×10^{-9}	3.71×10^{-7}	4.90×10^{-3}	7.58×10^{-5}	8.90×10^{-3}
	Cd	0.98	817.4	3	30	365	61	10950	9.77×10^{-11}	3.93×10^{-9}	1.20×10^{-5}	3.27×10^{-4}	
	Cr	2.28	817.4	3	30	365	61	10950	2.28×10^{-9}	9.18×10^{-8}	1.50×10^{-5}	6.12×10^{-3}	
	Mn	8.53	817.4	3	30	365	61	10950	8.53×10^{-9}	3.43×10^{-7}	6.00×10^{-4}	5.72×10^{-4}	
	Ni	7.07	817.4	3	30	365	61	10950	7.07×10^{-9}	2.84×10^{-7}	2.00×10^{-4}	1.42×10^{-3}	
	Pb	4.02	817.4	3	30	365	61	10950	4.02×10^{-9}	1.61×10^{-7}	4.20×10^{-4}	3.84×10^{-4}	
4	Ba	14.40	822.2	2	20	365	62	7300	1.44×10^{-8}	3.82×10^{-7}	4.90×10^{-3}	7.79×10^{-5}	8.11×10^{-3}
	Cd	1.37	822.2	2	20	365	62	7300	1.37×10^{-10}	3.62×10^{-9}	1.20×10^{-5}	3.02×10^{-4}	
	Cr	3.53	822.2	2	20	365	62	7300	3.53×10^{-9}	9.35×10^{-8}	1.50×10^{-5}	6.24×10^{-3}	
	Mn	8.33	822.2	2	20	365	62	7300	8.33×10^{-9}	2.21×10^{-7}	6.00×10^{-4}	3.68×10^{-4}	

	Elements	Individual exposure assessment									RfD*	HQ	HI
		Cs*	SA*	EV*	ED*	EF*	BW*	AT*	DAevent*	DAD*			
	Ni	5.91	822.2	2	20	365	62	7300	5.91×10^{-9}	1.57×10^{-7}	2.00×10^{-4}	7.84×10^{-4}	
	Pb	5.48	822.2	2	20	365	62	7300	5.48×10^{-9}	1.45×10^{-7}	4.20×10^{-4}	3.46×10^{-4}	
5	Ba	11.18	728.4	2	15	365	46	5475	1.12×10^{-8}	3.54×10^{-7}	4.90×10^{-3}	7.23×10^{-5}	1.01×10^{-2}
	Cd	1.10	728.4	2	15	365	46	5475	1.10×10^{-10}	3.47×10^{-9}	1.20×10^{-5}	2.89×10^{-4}	
	Cr	3.61	728.4	2	15	365	46	5475	3.61×10^{-9}	1.14×10^{-7}	1.50×10^{-5}	7.62×10^{-3}	
	Mn	7.57	728.4	2	15	365	46	5475	7.57×10^{-9}	2.40×10^{-7}	6.00×10^{-4}	4.00×10^{-4}	
	Ni	8.35	728.4	2	15	365	46	5475	8.35×10^{-9}	2.64×10^{-7}	2.00×10^{-4}	1.32×10^{-3}	
	Pb	5.02	728.4	2	15	365	46	5475	5.02×10^{-9}	1.59×10^{-7}	4.20×10^{-4}	3.79×10^{-4}	
6	Ba	13.48	728.4	2	30	365	46	10950	1.35×10^{-8}	4.27×10^{-7}	4.90×10^{-3}	8.71×10^{-5}	9.37×10^{-3}
	Cd	1.38	728.4	2	30	365	46	10950	1.38×10^{-10}	4.37×10^{-9}	1.20×10^{-5}	3.64×10^{-4}	
	Cr	2.93	728.4	2	30	365	46	10950	2.93×10^{-9}	9.28×10^{-8}	1.50×10^{-5}	6.19×10^{-3}	
	Mn	9.71	728.4	2	30	365	46	10950	9.71×10^{-9}	3.08×10^{-7}	6.00×10^{-4}	5.13×10^{-4}	
	Ni	12.04	728.4	2	30	365	46	10950	1.20×10^{-8}	3.81×10^{-7}	2.00×10^{-4}	1.91×10^{-3}	
	Pb	4.11	728.4	2	30	365	46	10950	4.11×10^{-9}	1.30×10^{-7}	4.20×10^{-4}	3.10×10^{-4}	
7	Ba	12.67	893.1	3	18	365	75	6570	1.27×10^{-8}	4.52×10^{-7}	4.90×10^{-3}	9.23×10^{-5}	8.23×10^{-3}
	Cd	1.28	893.1	3	18	365	75	6570	1.28×10^{-10}	4.58×10^{-9}	1.20×10^{-5}	3.81×10^{-4}	
	Cr	2.45	893.1	3	18	365	75	6570	2.45×10^{-9}	8.77×10^{-8}	1.50×10^{-5}	5.84×10^{-3}	
	Mn	6.81	893.1	3	18	365	75	6570	6.81×10^{-9}	2.43×10^{-7}	6.00×10^{-4}	4.05×10^{-4}	
	Ni	6.93	893.1	3	18	365	75	6570	6.93×10^{-9}	2.48×10^{-7}	2.00×10^{-4}	1.24×10^{-3}	
	Pb	3.18	893.1	3	18	365	75	6570	3.18×10^{-9}	1.13×10^{-7}	4.20×10^{-4}	2.70×10^{-4}	
8	Ba	13.21	766.1	2	12	365	52	4380	1.32×10^{-8}	3.89×10^{-7}	4.90×10^{-3}	7.94×10^{-5}	8.30×10^{-3}
	Cd	1.32	766.1	2	12	365	52	4380	1.32×10^{-10}	3.90×10^{-9}	1.20×10^{-5}	3.25×10^{-4}	
	Cr	2.95	766.1	2	12	365	52	4380	2.95×10^{-9}	8.70×10^{-8}	1.50×10^{-5}	5.80×10^{-3}	
	Mn	9.18	766.1	2	12	365	52	4380	9.18×10^{-9}	2.71×10^{-7}	6.00×10^{-4}	4.51×10^{-4}	
	Ni	9.48	766.1	2	12	365	52	4380	9.48×10^{-9}	2.79×10^{-7}	2.00×10^{-4}	1.40×10^{-3}	

	Elements	Individual exposure assessment									RfD*	HQ	HI
		Cs*	SA*	EV*	ED*	EF*	BW*	AT*	DAevent*	DAD*			
	Pb	3.46	766.1	2	12	365	52	4380	3.46×10^{-9}	1.02×10^{-7}	4.20×10^{-4}	2.43×10^{-4}	
9	Ba	11.76	866.7	2	20	365	70	7300	1.18×10^{-8}	2.91×10^{-7}	4.90×10^{-3}	5.94×10^{-5}	7.59×10^{-3}
	Cd	1.44	866.7	2	20	365	70	7300	1.44×10^{-10}	3.57×10^{-9}	1.20×10^{-5}	2.97×10^{-4}	
	Cr	3.67	866.7	2	20	365	70	7300	3.67×10^{-9}	9.10×10^{-8}	1.50×10^{-5}	6.06×10^{-3}	
	Mn	5.05	866.7	2	20	365	70	7300	5.05×10^{-9}	1.25×10^{-7}	6.00×10^{-4}	2.08×10^{-4}	
	Ni	6.47	866.7	2	20	365	70	7300	6.47×10^{-9}	1.60×10^{-7}	2.00×10^{-4}	8.01×10^{-4}	
	Pb	2.68	866.7	2	20	365	70	7300	2.68×10^{-9}	6.63×10^{-8}	4.20×10^{-4}	1.58×10^{-4}	
10	Ba	13.34	754.1	2	12	365	50	4380	1.33×10^{-8}	4.02×10^{-7}	4.90×10^{-3}	8.21×10^{-5}	9.38×10^{-3}
	Cd	1.31	754.1	2	12	365	50	4380	1.31×10^{-10}	3.94×10^{-9}	1.20×10^{-5}	3.29×10^{-4}	
	Cr	3.33	754.1	2	12	365	50	4380	3.33×10^{-9}	1.00×10^{-7}	1.50×10^{-5}	6.70×10^{-3}	
	Mn	6.56	754.1	2	12	365	50	4380	6.56×10^{-9}	1.98×10^{-7}	6.00×10^{-4}	3.30×10^{-4}	
	Ni	11.20	754.1	2	12	365	50	4380	1.12×10^{-8}	3.38×10^{-7}	2.00×10^{-4}	1.69×10^{-3}	
	Pb	3.46	754.1	2	12	365	50	4380	3.46×10^{-9}	1.04×10^{-7}	4.20×10^{-4}	2.49×10^{-4}	
11	Ba	8.99	753.0	3	20	365	50	7300	8.99×10^{-9}	4.06×10^{-7}	4.90×10^{-3}	8.29×10^{-5}	1.18×10^{-2}
	Cd	0.88	753.0	3	20	365	50	7300	8.81×10^{-11}	3.98×10^{-9}	1.20×10^{-5}	3.32×10^{-4}	
	Cr	2.71	753.0	3	20	365	50	7300	2.71×10^{-9}	1.22×10^{-7}	1.50×10^{-5}	8.16×10^{-3}	
	Mn	9.46	753.0	3	20	365	50	7300	9.46×10^{-9}	4.27×10^{-7}	6.00×10^{-4}	7.12×10^{-4}	
	Ni	9.50	753.0	3	20	365	50	7300	9.50×10^{-9}	4.29×10^{-7}	2.00×10^{-4}	2.15×10^{-3}	
	Pb	2.90	753.0	3	20	365	50	7300	2.90×10^{-9}	1.31×10^{-7}	4.20×10^{-4}	3.11×10^{-4}	
12	Ba	8.54	850.9	2	20	365	67	7300	8.54×10^{-9}	2.17×10^{-7}	4.90×10^{-3}	4.43×10^{-5}	1.18×10^{-2}
	Cd	1.05	850.9	2	20	365	67	7300	1.05×10^{-10}	2.68×10^{-9}	1.20×10^{-5}	2.23×10^{-4}	
	Cr	3.11	850.9	2	20	365	67	7300	3.11×10^{-9}	7.89×10^{-8}	1.50×10^{-5}	5.26×10^{-3}	
	Mn	5.86	850.9	2	20	365	67	7300	5.86×10^{-9}	1.49×10^{-7}	6.00×10^{-4}	2.48×10^{-4}	
	Ni	10.04	850.9	2	20	365	67	7300	1.00×10^{-8}	2.55×10^{-7}	2.00×10^{-4}	1.28×10^{-3}	
	Pb	2.08	850.9	2	20	365	67	7300	2.08×10^{-9}	5.29×10^{-8}	4.20×10^{-4}	1.26×10^{-4}	

	Elements	Individual exposure assessment									RfD*	HQ	HI
		Cs*	SA*	EV*	ED*	EF*	BW*	AT*	DAevent*	DAD*			
13	Ba	14.21	794.9	2	35	365	57	12775	1.42 x10^{-8}	3.96 x10^{-7}	4.90 x10^{-3}	8.09 x10^{-5}	1.11 x10^{-2}
	Cd	1.46	794.9	2	35	365	57	12775	1.46 x10^{-10}	4.07 x10^{-9}	1.20 x10^{-5}	3.40 x10^{-4}	
	Cr	4.53	794.9	2	35	365	57	12775	4.53 x10^{-9}	1.26 x10^{-7}	1.50 x10^{-5}	8.41 x10^{-3}	
	Mn	8.77	794.9	2	35	365	57	12775	8.77 x10^{-9}	2.45 x10^{-7}	6.00 x10^{-4}	4.08 x10^{-4}	
	Ni	11.82	794.9	2	35	365	57	12775	1.18 x10^{-8}	3.30 x10^{-7}	2.00 x10^{-4}	1.65 x10^{-3}	
	Pb	3.38	794.9	2	35	365	57	12775	3.38 x10^{-9}	9.43 x10^{-8}	4.20 x10^{-4}	2.25 x10^{-4}	
14	Ba	12.23	734.8	2	20	365	47	7300	1.22 x10^{-8}	3.82 x10^{-7}	4.90 x10^{-3}	7.80 x10^{-5}	9.51 x10^{-3}
	Cd	1.24	734.8	2	20	365	47	7300	1.24 x10^{-10}	3.87 x10^{-9}	1.20 x10^{-5}	3.22 x10^{-4}	
	Cr	3.44	734.8	2	20	365	47	7300	3.44 x10^{-9}	1.08 x10^{-7}	1.50 x10^{-5}	7.18 x10^{-3}	
	Mn	5.84	734.8	2	20	365	47	7300	5.84 x10^{-9}	1.83 x10^{-7}	6.00 x10^{-4}	3.04 x10^{-4}	
	Ni	9.19	734.8	2	20	365	47	7300	9.19 x10^{-9}	2.87 x10^{-7}	2.00 x10^{-4}	1.44 x10^{-3}	
	Pb	2.54	734.8	2	20	365	47	7300	2.54 x10^{-9}	7.94 x10^{-8}	4.20 x10^{-4}	1.89 x10^{-4}	
15	Ba	10.19	784.4	3	20	365	55	7300	1.02 x10^{-8}	4.36 x10^{-7}	4.90 x10^{-3}	8.90 x10^{-5}	1.08 x10^{-2}
	Cd	1.39	784.4	3	20	365	55	7300	1.39 x10^{-10}	5.96 x10^{-9}	1.20 x10^{-5}	4.96 x10^{-4}	
	Cr	2.63	784.4	3	20	365	55	7300	2.63 x10^{-9}	1.12 x10^{-7}	1.50 x10^{-5}	7.49 x10^{-3}	
	Mn	7.53	784.4	3	20	365	55	7300	7.53 x10^{-9}	3.22 x10^{-7}	6.00 x10^{-4}	5.37 x10^{-4}	
	Ni	8.34	784.4	3	20	365	55	7300	8.34 x10^{-9}	3.57 x10^{-7}	2.00 x10^{-4}	1.78 x10^{-3}	
	Pb	3.63	784.4	3	20	365	55	7300	3.63 x10^{-9}	1.55 x10^{-7}	4.20 x10^{-4}	3.70 x10^{-4}	
16	Ba	7.43	749.2	2	3	365	49	1095	7.43 x10^{-9}	2.27 x10^{-7}	4.90 x10^{-3}	4.64 x10^{-5}	7.58 x10^{-3}
	Cd	1.01	749.2	2	3	365	49	1095	1.01 x10^{-10}	3.10 x10^{-9}	1.20 x10^{-5}	2.58 x10^{-4}	
	Cr	2.62	749.2	2	3	365	49	1095	2.62 x10^{-9}	8.02 x10^{-8}	1.50 x10^{-5}	5.35 x10^{-3}	
	Mn	7.12	749.2	2	3	365	49	1095	7.12 x10^{-9}	2.18 x10^{-7}	6.00 x10^{-4}	3.63 x10^{-4}	
	Ni	8.13	749.2	2	3	365	49	1095	8.13 x10^{-9}	2.49 x10^{-7}	2.00 x10^{-4}	1.24 x10^{-3}	
	Pb	4.38	749.2	2	3	365	49	1095	4.38 x10^{-9}	1.34 x10^{-7}	4.20 x10^{-4}	3.19 x10^{-4}	
17	Ba	13.86	800.6	1	30	365	58	10950	1.39 x10^{-8}	1.91 x10^{-7}	4.90 x10^{-3}	3.90 x10^{-5}	3.63 x10^{-3}

	Elements	Individual exposure assessment Cs*	SA*	EV*	ED*	EF*	BW*	AT*	DAevent*	DAD*	RfD*	HQ	HI
	Cd	1.30	800.6	1	30	365	58	10950	1.30×10^{-10}	1.79×10^{-9}	1.20×10^{-5}	1.50×10^{-4}	
	Cr	2.35	800.6	1	30	365	58	10950	2.35×10^{-9}	3.25×10^{-8}	1.50×10^{-5}	2.17×10^{-3}	
	Mn	8.72	800.6	1	30	365	58	10950	8.72×10^{-9}	1.20×10^{-7}	6.00×10^{-4}	2.01×10^{-4}	
	Ni	12.23	800.6	1	30	365	58	10950	1.22×10^{-8}	1.69×10^{-7}	2.00×10^{-4}	8.44×10^{-4}	
	Pb	7.10	800.6	1	30	365	58	10950	7.10×10^{-9}	9.80×10^{-8}	4.20×10^{-4}	2.33×10^{-4}	
18	Ba	11.60	812.6	1	10	365	60	3650	1.16×10^{-8}	1.57×10^{-7}	4.90×10^{-3}	3.21×10^{-5}	2.64×10^{-3}
	Cd	0.83	812.6	1	10	365	60	3650	8.30×10^{-11}	1.12×10^{-9}	1.20×10^{-5}	9.37×10^{-5}	
	Cr	1.90	812.6	1	10	365	60	3650	1.90×10^{-9}	2.58×10^{-8}	1.50×10^{-5}	1.72×10^{-3}	
	Mn	3.19	812.6	1	10	365	60	3650	3.19×10^{-9}	4.33×10^{-8}	6.00×10^{-4}	7.21×10^{-5}	
	Ni	8.38	812.6	1	10	365	60	3650	8.38×10^{-9}	1.14×10^{-7}	2.00×10^{-4}	5.68×10^{-4}	
	Pb	4.97	812.6	1	10	365	60	3650	4.97×10^{-9}	6.73×10^{-8}	4.20×10^{-4}	1.60×10^{-4}	
19	Ba	12.09	754.5	1	3	365	50	1095	1.21×10^{-8}	1.82×10^{-7}	4.90×10^{-3}	3.72×10^{-5}	2.96×10^{-3}
	Cd	1.05	754.5	1	3	365	50	1095	1.05×10^{-10}	1.58×10^{-9}	1.20×10^{-5}	1.32×10^{-4}	
	Cr	2.21	754.5	1	3	365	50	1095	2.21×10^{-9}	3.33×10^{-8}	1.50×10^{-5}	2.22×10^{-3}	
	Mn	3.22	754.5	1	3	365	50	1095	3.22×10^{-9}	4.85×10^{-8}	6.00×10^{-4}	8.09×10^{-5}	
	Ni	5.11	754.5	1	3	365	50	1095	5.11×10^{-9}	7.71×10^{-8}	2.00×10^{-4}	3.86×10^{-4}	
	Pb	2.93	754.5	1	3	365	50	1095	2.93×10^{-9}	4.42×10^{-8}	4.20×10^{-4}	1.05×10^{-4}	
20	Ba	10.68	916.0	1	30	365	80	10950	1.07×10^{-8}	1.22×10^{-7}	4.90×10^{-3}	2.50×10^{-5}	2.48×10^{-3}
	Cd	1.03	916.0	1	30	365	80	10950	1.03×10^{-10}	1.18×10^{-9}	1.20×10^{-5}	9.80×10^{-5}	
	Cr	2.22	916.0	1	30	365	80	10950	2.22×10^{-9}	2.55×10^{-8}	1.50×10^{-5}	1.70×10^{-3}	
	Mn	8.01	916.0	1	30	365	80	10950	8.01×10^{-9}	9.17×10^{-8}	6.00×10^{-4}	1.53×10^{-4}	
	Ni	7.60	916.0	1	30	365	80	10950	7.60×10^{-9}	8.70×10^{-8}	2.00×10^{-4}	4.35×10^{-4}	
	Pb	2.58	916.0	1	30	365	80	10950	2.58×10^{-9}	2.95×10^{-8}	4.20×10^{-4}	7.02×10^{-5}	
21	Ba	6.14	746.9	1	6	365	49	2190	6.14×10^{-9}	9.36×10^{-8}	4.90×10^{-3}	1.91×10^{-5}	1.89×10^{-3}
	Cd	0.61	746.9	1	6	365	49	2190	6.07×10^{-11}	9.25×10^{-10}	1.20×10^{-5}	7.71×10^{-5}	

	Elements	Individual exposure assessment									RfD*	HQ	HI
		Cs*	SA*	EV*	ED*	EF*	BW*	AT*	DAevent*	DAD*			
	Cr	1.15	746.9	1	6	365	49	2190	1.15 x10^{-9}	1.76 x10^{-8}	1.50 x10^{-5}	1.17 x10^{-3}	
	Mn	5.39	746.9	1	6	365	49	2190	5.39 x10^{-9}	8.22 x10^{-8}	6.00 x10^{-4}	1.37 x10^{-4}	
	Ni	5.21	746.9	1	6	365	49	2190	5.21 x10^{-9}	7.94 x10^{-8}	2.00 x10^{-4}	3.97 x10^{-4}	
	Pb	2.34	746.9	1	6	365	49	2190	2.34 x10^{-9}	3.56 x10^{-8}	4.20 x10^{-4}	8.48 x10^{-5}	
22	Ba	8.45	850.6	2	10	365	67	3650	8.45 x10^{-9}	2.15 x10^{-7}	4.90 x10^{-3}	4.38 x10^{-5}	3.98 x10^{-3}
	Cd	0.77	850.6	2	10	365	67	3650	7.68 x10^{-11}	1.95 x10^{-9}	1.20 x10^{-5}	1.62 x10^{-4}	
	Cr	1.66	850.6	2	10	365	67	3650	1.66 x10^{-9}	4.22 x10^{-8}	1.50 x10^{-5}	2.81 x10^{-3}	
	Mn	4.61	850.6	2	10	365	67	3650	4.61 x10^{-9}	1.17 x10^{-7}	6.00 x10^{-4}	1.95 x10^{-4}	
	Ni	4.70	850.6	2	10	365	67	3650	4.70 x10^{-9}	1.19 x10^{-7}	2.00 x10^{-4}	5.96 x10^{-4}	
	Pb	2.75	850.6	2	10	365	67	3650	2.75 x10^{-9}	6.97 x10^{-8}	4.20 x10^{-4}	1.66 x10^{-4}	
23	Ba	8.50	844.6	1	3	365	62	1095	8.50 x10^{-9}	1.16 x10^{-7}	4.90 x10^{-3}	2.36 x10^{-5}	2.19 x10^{-3}
	Cd	0.87	844.6	1	3	365	62	1095	8.70 x10^{-11}	1.18 x10^{-9}	1.20 x10^{-5}	9.87 x10^{-5}	
	Cr	1.75	844.6	1	3	365	62	1095	1.75 x10^{-9}	2.39 x10^{-8}	1.50 x10^{-5}	1.59 x10^{-3}	
	Mn	3.78	844.6	1	3	365	62	1095	3.78 x10^{-9}	5.15 x10^{-8}	6.00 x10^{-4}	8.59 x10^{-5}	
	Ni	4.80	844.6	1	3	365	62	1095	4.80 x10^{-9}	6.54 x10^{-8}	2.00 x10^{-4}	3.27 x10^{-4}	
	Pb	2.06	844.6	1	3	365	62	1095	2.06 x10^{-9}	2.80 x10^{-8}	4.20 x10^{-4}	6.67 x10^{-5}	
24	Ba	10.50	932.6	1	10	365	84	3650	1.05 x10^{-8}	1.17 x10^{-7}	4.90 x10^{-3}	2.38 x10^{-5}	2.70 x10^{-3}
	Cd	1.06	932.6	1	10	365	84	3650	1.06 x10^{-10}	1.18 x10^{-9}	1.20 x10^{-5}	9.82 x10^{-5}	
	Cr	2.66	932.6	1	10	365	84	3650	2.66 x10^{-9}	2.95 x10^{-8}	1.50 x10^{-5}	1.97 x10^{-3}	
	Mn	5.29	932.6	1	10	365	84	3650	5.29 x10^{-9}	5.87 x10^{-8}	6.00 x10^{-4}	9.78 x10^{-5}	
	Ni	8.19	932.6	1	10	365	84	3650	8.19 x10^{-9}	9.10 x10^{-8}	2.00 x10^{-4}	4.55 x10^{-4}	
	Pb	2.09	932.6	1	10	365	84	3650	2.09 x10^{-9}	2.32 x10^{-8}	4.20 x10^{-4}	5.52 x10^{-5}	
25	Ba	10.45	741.0	1	6	365	48	2190	1.05 x10^{-8}	1.61 x10^{-7}	4.90 x10^{-3}	3.29 x10^{-5}	3.49 x10^{-3}
	Cd	1.07	741.0	1	6	365	48	2190	1.07 x10^{-10}	1.65 x10^{-9}	1.20 x10^{-5}	1.38 x10^{-4}	
	Cr	2.21	741.0	1	6	365	48	2190	2.21 x10^{-9}	3.42 x10^{-8}	1.50 x10^{-5}	2.28 x10^{-3}	

	Elements	Individual exposure assessment									RfD*	HQ	HI
		Cs*	SA*	EV*	ED*	EF*	BW*	AT*	DAevent*	DAD*			
	Mn	9.06	741.0	1	6	365	48	2190	9.06×10^{-9}	1.40×10^{-7}	6.00×10^{-4}	2.33×10^{-4}	
	Ni	9.09	741.0	1	6	365	48	2190	9.09×10^{-9}	1.40×10^{-7}	2.00×10^{-4}	7.01×10^{-4}	
	Pb	3.01	741.0	1	6	365	48	2190	3.01×10^{-9}	4.64×10^{-8}	4.20×10^{-4}	1.11×10^{-4}	
26	Ba	8.80	814.0	1	18	365	60	6570	8.80×10^{-9}	1.19×10^{-7}	4.90×10^{-3}	2.44×10^{-5}	3.53×10^{-3}
	Cd	0.90	814.0	1	18	365	60	6570	9.01×10^{-11}	1.22×10^{-9}	1.20×10^{-5}	1.02×10^{-4}	
	Cr	2.70	814.0	1	18	365	60	6570	2.70×10^{-9}	3.67×10^{-8}	1.50×10^{-5}	2.44×10^{-3}	
	Mn	9.83	814.0	1	18	365	60	6570	9.83×10^{-9}	1.33×10^{-7}	6.00×10^{-4}	2.22×10^{-4}	
	Ni	9.47	814.0	1	18	365	60	6570	9.47×10^{-9}	1.29×10^{-7}	2.00×10^{-4}	6.43×10^{-4}	
	Pb	2.96	814.0	1	18	365	60	6570	2.96×10^{-9}	4.02×10^{-8}	4.20×10^{-4}	9.58×10^{-5}	
27	Ba	7.90	818.2	1	25	365	61	9125	7.90×10^{-9}	1.06×10^{-7}	4.90×10^{-3}	2.16×10^{-5}	2.13×10^{-3}
	Cd	0.80	818.2	1	25	365	61	9125	7.99×10^{-11}	1.07×10^{-9}	1.20×10^{-5}	8.93×10^{-5}	
	Cr	1.67	818.2	1	25	365	61	9125	1.67×10^{-9}	2.25×10^{-8}	1.50×10^{-5}	1.50×10^{-3}	
	Mn	4.33	818.2	1	25	365	61	9125	4.33×10^{-9}	5.80×10^{-8}	6.00×10^{-4}	9.67×10^{-5}	
	Ni	5.63	818.2	1	25	365	61	9125	5.63×10^{-9}	7.55×10^{-8}	2.00×10^{-4}	3.78×10^{-4}	
	Pb	1.60	818.2	1	25	365	61	9125	1.60×10^{-9}	2.15×10^{-8}	4.20×10^{-4}	5.11×10^{-5}	
28	Ba	11.44	783.3	1	30	365	55	10950	1.14×10^{-8}	1.63×10^{-7}	4.90×10^{-3}	3.33×10^{-5}	4.85×10^{-3}
	Cd	1.37	783.3	1	30	365	55	10950	1.37×10^{-10}	1.95×10^{-9}	1.20×10^{-5}	1.62×10^{-4}	
	Cr	3.97	783.3	1	30	365	55	10950	3.97×10^{-9}	5.66×10^{-8}	1.50×10^{-5}	3.77×10^{-3}	
	Mn	9.13	783.3	1	30	365	55	10950	9.13×10^{-9}	1.30×10^{-7}	6.00×10^{-4}	2.17×10^{-4}	
	Ni	7.21	783.3	1	30	365	55	10950	7.21×10^{-9}	1.03×10^{-7}	2.00×10^{-4}	5.13×10^{-4}	
	Pb	4.59	783.3	1	30	365	55	10950	4.59×10^{-9}	6.54×10^{-8}	4.20×10^{-4}	1.56×10^{-4}	
29	Ba	7.70	867.4	1	25	365	70	9125	7.70×10^{-9}	9.54×10^{-8}	4.90×10^{-3}	1.95×10^{-5}	2.73×10^{-3}
	Cd	1.19	867.4	1	25	365	70	9125	1.19×10^{-9}	1.47×10^{-9}	1.20×10^{-5}	1.23×10^{-4}	
	Cr	2.01	867.4	1	25	365	70	9125	2.01×10^{-9}	2.50×10^{-8}	1.50×10^{-5}	1.66×10^{-3}	
	Mn	7.03	867.4	1	25	365	70	9125	7.03×10^{-9}	8.71×10^{-8}	6.00×10^{-4}	1.45×10^{-4}	

	Elements	Individual exposure assessment									RfD*	HQ	HI
		Cs*	SA*	EV*	ED*	EF*	BW*	AT*	DAevent*	DAD*			
	Ni	11.04	867.4	1	25	365	70	9125	1.10 x10^{-8}	1.37 x10^{-7}	2.00 x10^{-4}	6.84 x10^{-4}	
	Pb	3.28	867.4	1	25	365	70	9125	3.28 x10^{-9}	4.07 x10^{-8}	4.20 x10^{-4}	9.68 x10^{-5}	
30	Ba	7.63	795.8	1	30	365	57	10950	7.63 x10^{-9}	1.07 x10^{-7}	4.90 x10^{-3}	2.17 x10^{-5}	
	Cd	0.93	795.8	1	30	365	57	10950	9.35 x10^{-11}	1.31 x10^{-9}	1.20 x10^{-5}	1.09 x10^{-4}	
	Cr	2.15	795.8	1	30	365	57	10950	2.15 x10^{-9}	3.00 x10^{-8}	1.50 x10^{-5}	2.00 x10^{-3}	2.85 x10^{-3}
	Mn	6.17	795.8	1	30	365	57	10950	6.17 x10^{-9}	8.62 x10^{-8}	6.00 x10^{-4}	1.44 x10^{-4}	
	Ni	6.95	795.8	1	30	365	57	10950	6.95 x10^{-9}	9.71 x10^{-8}	2.00 x10^{-4}	4.85 x10^{-4}	
	Pb	2.75	795.8	1	30	365	57	10950	2.75 x10^{-9}	3.84 x10^{-8}	4.20 x10^{-4}	9.15 x10^{-5}	

* C (mg/kg)

*SA (cm)

*EV (event/day)

*EF (days/year)

*BW (kg)

*AT (days)

*DAevent (mg/cm^2/event)

*ADD (mg/kg-day)

*RfD (mg/kg-day)

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- Oral presentation at 4th International Conference on Public Health among Greater Mekong Sub-Regional Countries, 15-16 September 2012, Kunming, China
- Oral presentation at the 9th International Conference on Environmental and Public Health Management, 2-4 October 2012
- Poster presentation at the 9th International Conference on Environmental and Public Health Management, 2-4 October 2012