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

**Pornrat Kaewrueng[1, 2], Wattasit Siriwong[3, 4, *], Sangchom Siripanich[5]**

[1]International Postgraduate Programs in Environmental Management, Graduate School, Chulalongkorn University, Bangkok 10330, Thailand, [2]National Center of Excellence for Environmental and Hazardous Waste Managemet (NCE-EHWM), Chulalongkorn University, Bangkok 10330, Thailand, [3]College of Public Health Science, Chulalongkorn University, Bangkok 10330, Thailand, [4]Thai Fogarty ITREOH Center, Chulalongkorn University, Bangkok 10330, Thailand, [5]Occupational and Environmental Health Surveillance Sector, Bureau of Epidemiology, DDC MoPH. Thailand

**ABSTRACT:** The Ngooleum village in Roi-Et province is one of the largest producers of incense sticks in the northeastern region of Thailand. Heavy metals are present in the dyes used to color the incense sticks, and there is concern regading potential dermal exposure to these metals. The aim of this study was to assess the potential risk that such heavy metal exposure generates. Thirty-five small household factories were randomly selected for sample collection and one worker in each factory was interviewed face-to-face about factors potentially related to exposure. Heavy metals residue in each sample was extracted by microwave digestion, and analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES). The average residue concentrations (±SD) of Ba, Cd, Cr, Mn, Ni, and Pb on workers' 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 calculated dermal absorbed dose (DAD) of male workers (n=5) on six heavy metals exposure were $2.77\times10^{-7}$ mg/kg-day, $2.64\times10^{-9}$ mg/kg-day, $7.38\times10^{-8}$ mg/kg-day, $1.71\times10^{-7}$ mg/kg-day, $1.89\times10^{-7}$ mg/kg-day, and $8.98\times10^{-8}$ mg/kg-day, respectively. The hazard quotients (HQs) of six heavy metals were $5.64\times10^{-5}$, $2.20\times10^{-4}$, $4.92\times10^{-3}$, $2.85\times10^{-4}$, $9.46\times10^{-4}$, and $2.14\times10^{-4}$, respectively. The hazard index (HI) for total six heavy metals was $6.64\times10^{-3}$. The (DAD) of female workers (n=30) for six heavy metals were $2.58\times10^{-7}$ mg/kg-day, $2.68\times10^{-9}$ mg/kg-day, $6.39\times10^{-8}$ mg/kg-day, $1.66\times10^{-7}$ mg/kg-day, $1.95\times10^{-7}$ mg/kg-day, and $8.28\times10^{-8}$ mg/kg-day, respectively. The risk characterizations in term of hazard quotient (HQ) of these metals exposure for female workers were $5.26\times10^{-5}$, $2.24\times10^{-4}$, $4.26\times10^{-3}$, $2.77\times10^{-4}$, $9.74\times10^{-4}$, and $1.97\times10^{-4}$, respectively. The hazard index (HI) of total six heavy metals was $5.99\times10^{-3}$. In conclusion, both of the HQ values for each heavy metal and HI value for total six heavy metals were considerably less than one. Thus, it is concluded that these incense workers may not be receiving appreciable health risk from dermal occupational exposure to these heavy metals.

**Keywords:** Heavy metal, Dermal exposure, Risk assessment, Incense workers

## INTRODUCTION

Incense sticks are widely used, especially in Asian countries, and often for religious purposes [1]. The reasons why incense stick are used because each religion believes to use it for connection with god in many holy ceremonies or it use for sending soul of the deceased. Thailand, in which incense sticks are used extensively, produces them in several provinces such as Ayutthaya, Chiang Mai, Chainat, Singburi, Pathumthani, Uthaithani, and Roi-Et. In this study, Roi-Et was chosen because it is one of the largest incense stick producers in Northeastern region of Thailand and has many small household factories. The Ngooleum village in Dong Dang sub district, Chaturaphak Phiman district in Roi-Et province, which has 12 subvillages, or "Moo". Moo $12^{th}$ of this village was selected because its income from incense production is higher than that of other subvillages. The main occupation in the village is incense worker; other occupations are farmer, shallot growing, merchant, and employee for supporting income. This area produces many types of incense stick but incense stick that Thai people call "Toop-sad" is the most popular. The total length is about 20 centimeters; the upper part is mixed with sawdust and other components, and the lower part is generally colored by dipping in red or

* *Correspondence to: Wattasit Siriwong*
*E-mail: wattasit.s@chula.ac.th*

pink dye. The dyeing color is commonly a synthetic color powder that may contain heavy metals such as lead, cadmium, and zinc. The heavy metal concentration level depends on trade name and mixing ratio between dyeing color and water in each small household factory. The usual incense stick making process has 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. Among these steps, packing may cause the highest risk of dermal exposure because most workers pack incense products without hand protection. Heavy metals can cause long-term health problems such as cancer, kidney damage, nervous system damage, skin changes, impaired cognitive, lethargy, insomnia, and emotional instability. Acute effects can also occur, including headaches, skin rash, cramps, vomiting, sweating and difficulty breathing [2].

This study focused on dermal exposure to heavy metals in the dyes used in incense production. Thus, hand wipe technique [3-5] was employed to collect heavy metal residues on workers' hands. Findings were then used in risk assessment [6].

## METHODS

### *Sampling*

Roi-Et is located the northeastern region of Thailand. The area is divided into 20 districts, 193 sub districts, and 2,311 villages [7]. In the study, Moo 12 of Ngooleum village in Dongdang subdistrict, Chaturaphak Phiman disstrict was selected because the main occupation of villagers is incense production, and because this village has higher income from incense production than other local villages.

In the study area, there were around 100 small household factories, of which 35 household factories chosen randomly by house number for inclusion in the study [8]. Dissolved dye, incense stick, and hand wipe samples were collected from each household factory. Workers responsible for packing incense were chosen randomly to collect samples by gauze wiping technique. For each factory, 20 ml of dissolved dye samples and incense stick samples were collected and kept in plastic bottles in plastic bags until analysis.

In the gauze wiping technique, two 20% isopropanol gauze pads wipe the hand surface side to side in "Z" wipe pattern, both vertically and horizontally, covering the front and sides and the fingers, 10 seconds per pad [3, 4, 9]. Working day of incense workers was separated into 2 events in the morning and afternoon. Thirty-five workers were collected 3 hand wiping samples: before working, after working by non-using gloves, and after washing hands during morning. And selected 10 small household factories from those 35 households for were assigned to use gloves and hand wipe samples were collected after working from these factories later on.

A three-part questionnaire for surveying dermal exposure to heavy metal was completed. One hundred participants including packing workers from 35 household factories were chosen for question by face-to-face interview in the morning before the workers start their daily work. The questionnaire queried age, gender, individual exposure parameters, and subjective signs and symptoms potentially related to dermal heavy metal exposure.

### *Chemical analysis*

Samples were digested using microwave digester in the extraction process before quantifying heavy metal concentrations [10]. The digested samples were analyzed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) for six heavy metal concentrations i.e. barium (Ba), cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni), and lead (Pb). Quality control involves information on limit of detection (LOD), method recovery, and relative standard deviations (RSD). The LOD of Ba, Cd, Cr, Mn, and Ni of dissolved dye, incense stick, and gauze wiping pad were $5.0 \times 10^{-3}$ ppm except Pb was $1.0 \times 10^{-3}$ ppm. The acceptable 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. The RSDs of dissolved dye, incense stick, and gauze-wiping pad of those heavy metals in the range of 3.8 to 9.3%, 4.1 to 9.0%, and 5.4 to 8.9%, respectively.

### *Risk assessment*

Risk assessment is the process that estimates the likelihood of risk and harmful health effect in humans exposed to chemical substances. Classical risk assessment consists of four basic steps (1) hazard identification (2) dose response assessment (3) exposure assessment, and (4) risk characterization [5, 6]. In this study, the objective of hazard identification step was to identify six heavy metals as barium (Ba), cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni), and lead (Pb). The emphasis was on their non-carcinogenic effects. The dose response assessment was done for assessing the potential relationship between non-carcinogenic effect and the amount of those heavy metals in step 1 in terms of dermal

**Table 1** Description and value of each parameter in the formulas

| Parameters | Description | Unit | Value | |
|---|---|---|---|---|
| | | | **Male (n=5)** | **Female (n=30)** |
| SA | Surface area | $cm^2$ | 903.1 | 803.0 |
| DAevent | Absorbed dose per event | $mg/cm^2$-event | Chemical-specific | |
| EV | Event frequency | event/day | 1.8 | 1.7 |
| ED | Exposure duration | years | 19.0 | 18.7 |
| EF | Exposure frequency | day/year | 365 | 365 |
| BW | Body weight | kg | 64.2 | 58.3 |
| AT | Averaging time for non carcinogen | days | 365 | 365 |
| C | Heavy metal concentrations on both hands | mg/kg | - | - |
| CF | Conversion factor | kg/mg | $10^{-6}$ | $10^{-6}$ |
| AF | Adherence factor of soil to skin (US EPA, 2004) | ($mg/cm^2$- event) | 0.1 | 0.1 |
| ABS | Dermal absorption fraction | - | 0.01, 0.001* | 0.01, 0.001* |
| H | Height | cm | 167.2 | 156.0 |
| W | Weight | kg | 64.2 | 58.3 |
| $a_0$ | Constant values (US EPA, 1997) | - | 0.0257 | 0.0131 |
| $a_1$ | Constant values (US EPA, 1997) | - | 0.573 | 0.412 |
| $a_2$ | Constant values (US EPA, 1997) | - | -0.218 | 0.0274 |

* for Cd

reference dose ($RfD_d$). $RfD_d$ is depended on the assumption that thresholds of toxic effect for non-carcinogenic effect. The RfD is presented in unit mg/kg-day and the RfD value specific to each substance [11]. The $RfD_d$ of Ba, Cd, Cr, Mn, Ni, and Pb were 4.90 $x10^{-3}$, 1.20 $x10^{-5}$, 1.50 $x10^{-5}$, 6.00 $x10^{-4}$, 2.00 $x10^{-4}$, and 4.20 $x10^{-4}$ mg/kg-day, respectively. The main route of the exposure is dermal contact, so the exposure assessment step use dermal absorbed dose (DAD) formula (see Equations 1, 2, and 3) to calculate dose of incense workers through dermal route. The values of each parameter in DAD formula were different in each worker (see Table 1). The calculations were as follow [12];

$$DAD\ (mg/kg\text{-}day) = \frac{(DAevent \times SA \times EV \times ED \times EF)}{(BW \times AT)} \quad (1)$$

$$DAevent\ (mg/cm^2\text{-}event) = C \times CF \times AF \times ABS \quad (2)$$

$$SA\ (cm^2) = a_0 W^{a2} H^{a1} \quad (3)$$

Risk characterization step in the study, the toxicity was classified as non-carcinogen. The potential risk is compared between dermal absorbed dose (DAD) and reference dose ($RfD_d$) in hazard quotient (HQ) formula for single substance (see *Equation* 4). For multiple substance or multiple routes, use hazard index (HI) to calculate the non-carcinogenic risk (see *Equation* 5). If calculated HQ > 1, there is concern that there may be excess non-carcinogenic risk [5, 13].

$$HQ = \frac{DAD}{RfD_d} \quad (4)$$

$$HI = \Sigma\ HQ \quad (5)$$

## RESULTS AND DISCUSSION

### *Heavy metal concentrations in dissolved dye, incense stick, and hand wipe samples on workers' hands*

In dissolved dye, the average concentration (±SD) of the six heavy metals as Ba, Cd, Cr, Mn, Ni, and Pb 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, and 0.90±0.05 mg/L, respectively. The average concentration (±SD) of those heavy metals 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, and 0.27±0.05 mg/kg, respectively. The heavy metal concentrations on hands from incense workers were reported separately to male and female workers because that related with hand surface area. The average concentration (±SD) of Ba, Cd, Cr, Mn, Ni, and Pb on male workers' hands were 12.62±1.21 mg/kg, 1.20±0.22 mg/kg, 3.36±0.92 mg/kg, 7.81±1.23 mg/kg, 8.63±2.56 mg/kg, and 4.10±2.02 mg/kg, respectively. The average concentration (±SD) of Ba, Cd, Cr, Mn, Ni, and Pb on female workers' hands were 10.76±2.36 mg/kg, 1.12±0.23 mg/kg, 2.67±0.78 mg/kg, 6.93±2.00 mg/kg, 8.13±2.20 mg/kg, and 3.46±1.19 mg/kg, respectively.

The least significant different (LSD) of posteriori

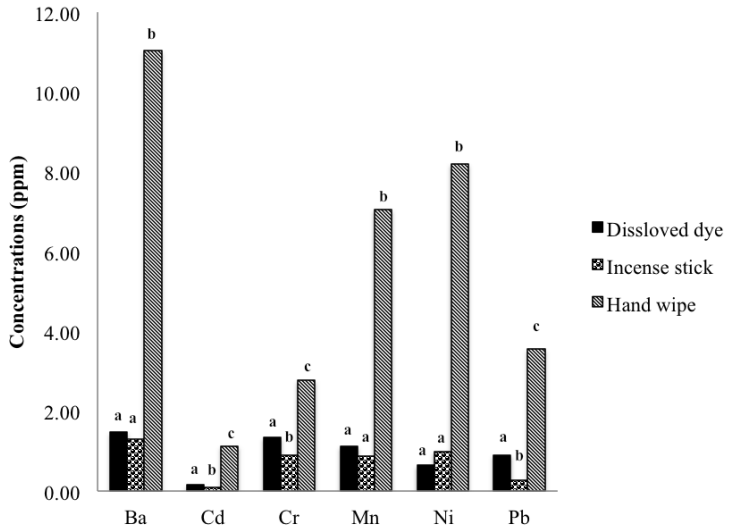



**Figure 1** Heavy metal concentrations of dissolved dye, incense stick, and on workers' hands (the mean concentrations with the different letter are significantly different at p≤0.05)

**Table 2** The average heavy metal concentrations (mg/kg) during working of incense workers

| Elements | Average concentration (±SD) (mg/kg) | | | |
|---|---|---|---|---|
| | Before working (n=35) | After working (non-using gloves) (n=35) | After washing hand (n=35) | After working (using gloves) (n=10) |
| 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 |

comparison (Post hoc) was used to compare the average heavy metal concentrations between dissolved dye and incense stick, dissolved dye and hand wiping sample, and incense stick and hand wiping sample. These heavy metal concentrations in three matrices can arrange from highest to lowest were hand wiping, dissolved dye, and incense stick samples. Because hand wiping samples were collected from workers' hands that had surface more than dissolved dye and incense stick, the samples were high level of heavy metal concentrations. Another reason was during working incense process around 3-4 hours per event that was made accumulated dyeing color on hands. Dissolved dye had heavy metal concentrations more than incense stick because a bundle of incense stick samples had bamboo part and dyeing color, thus when calculate heavy metal concentrations in term of mg/kg was lower than dissolved dye. The results found 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 ($p$<0.001). The mean difference of Ba, Cd, Cr, Mn, Ni, and Pb between dissolved dye and hand wiping sample were statistically significant ($p$<0.001) and between incense stick and hand wiping sample were statistically significant ($p$<0.001). Figure 1 showed the bar graph of the average concentrations for dissolved dye, incense stick, and hand wiping samples with the different letter were significantly different at p≤0.05. When compared the average heavy metal concentrations of dissolved dye and incense stick with hand wiping sample, the results found that were statistically significant.

***Heavy metal concentrations on workers' hands during working***

Thirty-five packing workers were collected three times of hand wiping samples: before working, after working, and after washing hands and then randomly selected ten workers to collect hand wiping sample after working by using gloves. The reason why that only packing incense workers were collected the samples because in the questionnaire indicated the packing incense workers contacted

**Table 3** Summary of dermal exposure and risk values of incense workers

| | Elements | DAD | | $RfD_d$ | HQ | | HI | |
|---|---|---|---|---|---|---|---|---|
| | | Mean | RME | | Mean | RME | Mean | RME |
| **Male** | Ba | $2.77 \times 10^{-7}$ | NC | $4.90 \times 10^{-3}$ | $5.64 \times 10^{-5}$ | NC | $6.64 \times 10^{-3}$ | NC |
| | Cd | $2.64 \times 10^{-9}$ | NC | $1.20 \times 10^{-5}$ | $2.20 \times 10^{-4}$ | NC | | |
| | Cr | $7.38 \times 10^{-8}$ | NC | $1.50 \times 10^{-5}$ | $4.92 \times 10^{-3}$ | NC | | |
| | Mn | $1.71 \times 10^{-7}$ | NC | $6.00 \times 10^{-4}$ | $2.85 \times 10^{-4}$ | NC | | |
| | Ni | $1.89 \times 10^{-7}$ | NC | $2.00 \times 10^{-4}$ | $9.46 \times 10^{-4}$ | NC | | |
| | Pb | $8.98 \times 10^{-8}$ | NC | $4.20 \times 10^{-4}$ | $2.14 \times 10^{-4}$ | NC | | |
| **Female** | Ba | $2.58 \times 10^{-7}$ | $1.02 \times 10^{-6}$ | $4.90 \times 10^{-3}$ | $5.26 \times 10^{-5}$ | $2.09 \times 10^{-4}$ | $5.99 \times 10^{-3}$ | $2.79 \times 10^{-2}$ |
| | Cd | $2.68 \times 10^{-9}$ | $1.06 \times 10^{-8}$ | $1.20 \times 10^{-5}$ | $2.24 \times 10^{-4}$ | $8.68 \times 10^{-4}$ | | |
| | Cr | $6.39 \times 10^{-8}$ | $3.20 \times 10^{-7}$ | $1.50 \times 10^{-5}$ | $4.26 \times 10^{-3}$ | $2.02 \times 10^{-2}$ | | |
| | Mn | $1.66 \times 10^{-7}$ | $7.00 \times 10^{-7}$ | $6.00 \times 10^{-4}$ | $2.77 \times 10^{-4}$ | $1.17 \times 10^{-3}$ | | |
| | Ni | $1.95 \times 10^{-7}$ | $8.87 \times 10^{-7}$ | $2.00 \times 10^{-4}$ | $9.74 \times 10^{-4}$ | $4.36 \times 10^{-3}$ | | |
| | Pb | $8.28 \times 10^{-8}$ | $4.68 \times 10^{-7}$ | $4.20 \times 10^{-4}$ | $1.97 \times 10^{-4}$ | $1.06 \times 10^{-3}$ | | |
| **Total** | Ba | $2.58 \times 10^{-7}$ | $1.00 \times 10^{-6}$ | $4.90 \times 10^{-3}$ | $5.26 \times 10^{-5}$ | $2.04 \times 10^{-4}$ | $6.02 \times 10^{-3}$ | $2.84 \times 10^{-2}$ |
| | Cd | $2.64 \times 10^{-9}$ | $1.04 \times 10^{-8}$ | $1.20 \times 10^{-5}$ | $2.20 \times 10^{-4}$ | $8.64 \times 10^{-4}$ | | |
| | Cr | $6.48 \times 10^{-8}$ | $3.12 \times 10^{-7}$ | $1.50 \times 10^{-5}$ | $4.32 \times 10^{-3}$ | $2.08 \times 10^{-2}$ | | |
| | Mn | $1.65 \times 10^{-7}$ | $6.83 \times 10^{-7}$ | $6.00 \times 10^{-4}$ | $2.75 \times 10^{-4}$ | $1.14 \times 10^{-3}$ | | |
| | Ni | $1.92 \times 10^{-7}$ | $8.66 \times 10^{-7}$ | $2.00 \times 10^{-4}$ | $9.59 \times 10^{-4}$ | $4.33 \times 10^{-3}$ | | |
| | Pb | $8.30 \times 10^{-8}$ | $4.57 \times 10^{-7}$ | $4.20 \times 10^{-4}$ | $1.98 \times 10^{-4}$ | $1.09 \times 10^{-3}$ | | |

NC = not calculated (small number of male subjects)

dyeing color directly via their hands skin but others workers rarely contacted to dyeing color. Table 2 showed the average heavy metal concentrations (±SD) of the four times sampling. Wilcoxon test was used to compare the average heavy metal concentration between two times of sampling, before and after working by non- using gloves were compared the average heavy metal concentrations, the result was statistically significant difference ($p$<0.001) for all of heavy metals. Before working still found a little of those heavy metals because the accumulation from previous days but the heavy metal concentrations were increase when after working and the percentage increasing relatively 95.3-97.8%. The concentration of after working by non-using gloves and after washing hands was statistically significant difference ($p$<0.001) for all heavy metals because washing hands can wash some dyeing color that stick on hands and the percentage of heavy metal concentrations decreasing relatively 88.1-97.2%. Before working and after washing hands, the mean difference of all heavy metal concentrations were statistically significant ($p$<0.001) except Pb was not statistically significant ($p$=0.027) and the percentage of heavy metal concentrations that remaining relatively 15.9-68.2%. And the last paired was after working by non-using gloves and using gloves that was tested because in the questionnaire indicated all participants did not use gloves when working. The heavy metal concentrations of after working by non-using gloves were very higher than by using gloves due to gloves wearing can protect dyeing color stick on hands. The comparison of the average heavy metal concentrations were statistically significant difference ($p$<0.001) and the percentage of heavy metal concentrations that decreasing relatively 97.1-99.8%.

**Risk assessment**

Table 3, the study was presented value of DAD, $RfD_d$, HQ, and HI at the mean and the reasonable maximum exposure (RME). The RME is the worst-case scenario that evaluates exposures that higher than average. The 95$^{th}$ percentile is used to evaluate RME because the situation involves the uncertainty of concentration value [5, 12]. The results showed that HI results of mean for male were $6.64 \times 10^{-3}$. HI of mean and RME in female were $5.99 \times 10^{-3}$ and $2.79 \times 10^{-2}$ and results of total thirty-five workers were $6.02 \times 10^{-3}$ and $2.84 \times 10^{-2}$ , respectively.

Both of HQ and HI results as well as mean and RME were less than one that means the potential risk of this case study was no non-carcinogenic risk [5, 12].

**Subjective signs and symptoms**

Participants reported diseases such as allergy, migraine, gastritis, hypertension, liver disease, and kidney disease. Some symptoms from working related to heavy metal exposure [14-17] were presented i.e. hand eczema, skin rash, cramp, vomit, sweat, inconvenient breathing, and headache (Table 4).

**Table 4** Reported symptom rates in Moo 12th subvillage, Ngooleum village in Roi-Et province, Thailand

| Characteristics | Incense workers | | | |
|---|---|---|---|---|
| | Male | | Female | |
| | (n=65) | % | (n=35) | % |
| **Diseases** | | | | |
| Allergy | 1 | 1.50 | 0 | 0.00 |
| Migraine | 0 | 0.00 | 3 | 8.60 |
| Gastritis | 2 | 3.10 | 0 | 0.00 |
| Hypertension | 0 | 0.00 | 1 | 2.90 |
| Liver disease | 2 | 3.10 | 0 | 0.00 |
| Kidney disease | 1 | 1.50 | 1 | 2.90 |
| Nothing | 59 | 90.80 | 29 | 82.90 |
| Lymph node cancer | 0 | 0.00 | 1 | 2.90 |
| **Symptoms from working** | | | | |
| ***Hand eczema*** | | | | |
| Ever | 2 | 3.10 | 4 | 11.40 |
| Never | 63 | 96.90 | 31 | 88.60 |
| ***Skin rash*** | | | | |
| Ever | 8 | 12.30 | 9 | 25.70 |
| Never | 57 | 87.70 | 26 | 74.30 |
| ***Cramp*** | | | | |
| Ever | 10 | 15.40 | 11 | 31.40 |
| Never | 55 | 84.60 | 24 | 68.60 |
| ***Vomit*** | | | | |
| Ever | 2 | 3.10 | 2 | 5.70 |
| Never | 63 | 96.90 | 33 | 94.30 |
| ***Sweat*** | | | | |
| Ever | 39 | 60.00 | 15 | 42.80 |
| Never | 26 | 40.00 | 20 | 57.10 |
| ***Inconvenient breathing*** | | | | |
| Ever | 14 | 21.50 | 2 | 5.70 |
| Never | 51 | 78.50 | 33 | 94.30 |
| ***Headache*** | | | | |
| Ever | 9 | 13.80 | 15 | 42.90 |
| Never | 56 | 86.20 | 20 | 57.10 |

## CONCLUSIONS

The study found six heavy metals such as barium (Ba), cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni), and lead (Pb) in dyeing color, incense stick, and hand wiping sample. For this household occupation, male workers had higher average heavy metal residues compare to female workers related to exposure factors such as body weight, hand surface, exposure duration, and averaging time. Non- carcinogenic risk assessment on this study concluded that the incense workers might not be getting undue risk from these heavy metals via dermal route. However, the result of questionnaire indicated some sign and symptoms related to heavy metal exposure. Thus, it might be suggested that incense workers should be have self-protection practices for long-term heavy metal exposure such as hand washing after working time and glove using because these practices can reduce heavy metal residues on their hands approximately 88.0 - 97.2 % and 97.1 - 99.8 %, respectively.

## ACKNOWLEDGEMENT

We are grateful for financial support from The National Center of Excellence for Environmental and Hazardous Waste Management (NCE-EHWM) and CU Graduate School Thesis Grant of Graduate School from Chulalongkorn University. We also thank the Thai Fogarty ITREOH Center (Grant Number: D43 TW007849 Fogarty International Center, National Institutes of Health) for partial financial support and laboratory training.

## REFERENCES

1. Lin TC, Krishnaswamy G, Chi DS. Incense smoke: clinical, structure and molecular effects on airway disease. Clin Mol Allergy. 2008: 25; 6(1): 3.
2. Rook A, Wilkinson DS, Ebling FJB, Champion RH, Burton JL. Texbook of dermatology. 4th ed. [S.l]: Blackwell Science Publications; 2004.
3. Duggan MJ. Inskip MJ, Rundle SA, Moorcroft JS. Lead in playground dust and on the hands of schoolchildren. Sci Total Environ. 1985 Jul; 44(1): 65-79.
4. Stering AD, Roegner CK, Lewis DR, Luke AD, Wilder

CL, Burchette MS. Evaluation of four sampling methods for determining exposure of children to lead-contaminated household dust. Environ Res. 1999 Aug; 81(2): 130-41.

5. Taneepanichskul N, Siriwong W, Siripattanakul S, Pongpanich S, Robson M. Risk Assessment for chlorpyrifos (organophosphate pesticide) associated with dermal exposure in chilli-growing farmers at Ubon Rachathani province, Thailand. J Health Res. 2010; 24 (Suppl 2): 149-56.
6. USEPA United State Environmental Protection Agency. Human health risk assessment, the four basic steps of risk assessment; 2010. [cited 2011August 19]. Available from: http://www.epa.gov/risk_assessment/health-risk.htm
7. Ministry of interior. Incense stick at Ngooleum village, Roi Et province. [cited 2011 August 10]. Available from : http://www.otoptoday.com/wisdom/provinces/northeastern/ร้อยเอ็ด/1313494841#section-15438
8. Jaipieam S. Risk assessment of multi-route exposure to organophosphate pesticide of vegetable growers: a case study at Bang rieng subdistrict, Khuan nieng district, Songkhla province [Dissertation, Environmental Management Interdisciplinary Program]. Bangkok: Chulalongkorn University; 2008.
9. American Society for Testing and Materials. ASTM D 6966-08: standard practice for collection of settle dust samples using wipe sampling methods for subsequent determination of metals; 2008.
10. SGS milestone microwave laboratory system: wood chip: digestion application note DG-EN-19,organo-metallic pigment. Digestion application note DG-CA-04; 2004.
11. Integrated Risk Information System. Reference dose (RfD): description and use in health risk assessment; 1993. [cited 2012 October 10]. Available from: http://www.epa.gov/iris/rfd.htm
12. USEPA United State Environmental Protection Agency. Risk assessment guideline for superfund vol. 1: human health evaluation manual, part E : supplemental guidance from dermal risk assessment. Washington, DC.: USEPA; 2004.
13. Siriwong W, Thirakhupt K, Sitticharoenchai D, Robson M. Accumulation of organochlorine pesticide residues in aquatic plants. J Sci Res Chula Univ. 2007; 32: 7-14.
14. ATSDR. Barium and barium compound. Atlanta, Georgia: United States Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry; 2005.
15. ATSDR. CADMIUM CAS # 7440-43-9. Atlanta, Georgia: United States Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry; 1999.
16. ATSDR. Toxicological profile for chromium. Atlanta, Georgia: United States Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry; 2000.
17. World Health Organization [WHO]. Cadmium: international programme on chemical safety (environmental health criteria 134. Geneva: WHO; 1992.