Biomonitoring of Heavy Metals among Nielloware Workers in Nakhon Sri Thammarat Province

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Objective: *To determine lead and mercury concentrations in biological samples from nielloware workers, to describe the association between occupational lifestyle, work position, work environment, behavioral factors, acute and chronic neurological symptoms, and levels of metals in biological samples.*

Material and Method: *A cross-sectional study was conducted by interviewing 45 nielloware workers and 45 matched non-exposed persons living in the municipality of Nakhon Si Thammarat Province, Thailand. Blood and urine samples were collected to determine lead and mercury concentrations by atomic absorption spectrophotometer.*

Results: *The blood lead levels (7.30 µg/dl) and urinary mercury levels (3.30 µg/g creatinine) of the nielloware workers were significantly higher than the control group ($p < 0.001$). Income, working environmental conditions, work position, duration of work, personal protective equipment (PPE) and personal hygiene, had significant associations with blood lead and urinary mercury levels ($p < 0.05$). A significant positive correlation was found between income and blood-lead level ($r = 0.968$, $p < 0.001$) and urinary-mercury level ($r = 0.661$, $p = 0.004$). The nielloware workers developed acute and chronic symptoms, such as headaches, rash, fatigue, tightness in the chest, loss of consciousness, abnormal tiredness and headache at least once a week and those who developed symptoms had significantly higher heavy metal levels than those who did not at $p < 0.05$.*

Conclusion: *The blood lead and urinary mercury levels in nielloware workers were significantly higher than those in the control subjects. The significant associations were found between income, work position, PPE and personal hygiene and blood lead and urinary mercury levels.*

Keywords: *Biomonitoring, Heavy metals, Nielloware workers*

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Niello is the art of making receptacles by means of the application of a lead amalgam, superimposed upon or poured into incised designs. The type of receptacle created is called "nielloware"[1]. The nielloware work has 10 main activities including (1) making the niello amalgam, (2) shaping the object, (3) drawing the patterns, (4) engraving or chiseling, (5) applying the niello, (6) filling the surface of the object, (7) reshaping, (8) polishing, (9) engraving and (10) burnishing the object[2]. For gold-encrusted nielloware, the niello object was coated with gold and quicksilver (mercury) to transform silver niello into gold-encrusted nielloware. Only nielloware specialists are able to do this process. Exposure to heavy metals is a ubiquitous hazard among nielloware industry workers. The high-risk stages of the nielloware process include exposure to metallic fumes while making the niello, mercury vapor when applying gold amalgam and metallic dust when filling and polishing the object's surfaces. Heavy-metal exposure has been shown to cause a variety of acute and chronic symptoms. Acute symptoms include headaches, blurred vision, nausea or vomiting, rashes, and dermatitis. Chronic symptoms are usually associated with behavioral abnormalities and structural and functional abnormalities involving the brain and central nervous system[3]. In addition,

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the International Agency for Research on Cancer (IARC) has classified inorganic lead as a possible human carcinogen[4]. A literature review of heavy-metal exposure and health outcomes in jewelry workers found many acute and chronic pulmonary disorders[5-8]. In addition, potential toxicities causing neurological symptoms can occur[9-11] because elemental mercury is used for applying the gold amalgam. The present study to measure several metals in biological samples has never been done. It is a typical exposure of nielloware workers in Thailand. The present study would help to set up a health surveillance program for nielloware workers. The objectives of the current study were to determine lead and mercury concentration in biological samples of nielloware workers, to describe the association between occupational life styles, work position, working environment, behavioral factors, acute and chronic neurological symptoms, and levels of metals in biological samples.

Material and Method

In this cross-sectional study, biomonitoring samples were collected from nielloware workers in Nakhon Sri Thammarat, between October and December 2009. This research was approved by the Ethics Committee of the Faculty of Tropical Medicine, Mahidol University (MUTM 2009-033-01).

Study population and samples

The present study population comprised nielloware workers who lived in the municipality of Nakhon Sri Thammarat. The inclusion criteria for the exposed group were nielloware workers aged 20 to 60 years, in occupational contact with heavy metals and who had worked for at least one year. They agreed to participate in the study and provided written informed consent. Forty-five exposed subjects were recruited into the present study. Twenty-seven exposed subjects were male and 18 female. All worked in the assembly section. The non-exposed group (45 persons) was selected from the general population living in the same area, and was people who did not have occupational contact with these metals. They were matched for age and sex with the exposed group.

Sample collection

The 90 subjects (45 exposed and 45 non-exposed) were interviewed using a questionnaire. The biological samples, whole blood and urine, were collected at the end of the workshift and the first urination in the morning, respectively.

Questionnaire

The questionnaire consisted of general characteristics, occupational lifestyle, working position, working environment, personal hygiene and the development of any acute and chronic neurological symptoms. Acute symptoms were a short course after exposure to heavy metals in nielloware processes lasting seven days. Chronic neurological symptoms were neurological symptoms lasting three months or longer. Direct observation was also used to confirm the interview results.

Whole blood collection

The collection method for whole blood samples followed the NIOSH method 8003/1994[12]. Whole blood samples (3 ml) were obtained by venipuncture, and kept in metal-free tubes with heparin as anticoagulant. Special precautions were taken to guard against environmental contamination. The whole blood samples were not centrifuged and were mixed immediately and placed in containers with ice packs to maintain a temperature of approximately 4°C, controlled by thermometer at this temperature prior to analysis.

Urine collection

The spot urine samples (30 ml) were collected from the first urination in the morning. Ten milliliters of urine samples were separated into containers for urinary analysis and 5 ml for urine creatinine determination. The remaining samples were separated in metal-free test tubes. The urine samples were frozen at -20°C and transferred to the laboratory for analysis.

At the end of their work shifts, the subjects were also interviewed about their general characteristics, including work-related factors and any acute-chronic neurological symptoms.

Blood and urine samples were collected on October 11, 2009, at the home of each subject. Whole blood samples were transferred to the laboratory at the Central Equipment Unit, Faculty of Tropical Medicine, Mahidol University, and urine samples were transferred to the Faculty of Medical Technology, Mahidol University, for analysis on October 12, 2009.

Heavy metal analysis

Lead

The lead determination method for whole blood was slightly modified from that recommended by the Hitachi Company [13]. One hundred microliters of whole blood were transferred to an acid-washed polyethylene tube and 900 μl of diluted solution (0.2% ammonium dihydrogen phosphate + 0.1% Triton X-100 solution) were added. Two milliliters of blood sample were mixed and then transferred to a sample cup.

Whole blood-lead was analyzed by graphite furnace atomic absorption spectrophotometer (Hitachi Model Z-8200). Whole blood-lead was measured at a wavelength of 283.3 nm, with a slit width of 1.30 nm. Supply of electricity to lead hollow cathode lamp was at 12 nm. The temperature stage included drying at 50-140°C, ashing at 400-500°C, atomizing at 2,000°C, cleaning at 2,400°C and cooling at room temperature.

Calibration, recovery and reproducibility

Determination of whole blood-lead level was calibrated by preparing a series of standard additions, *i.e.* 0, 5, 10, 20, 30 and 50 μg/dl. The correlation coefficient (r) between the lead concentration in the authentic lead solution and absorption intensity was 0.9993. The limit of detection (LOD) was 4.00 μg/dl. The accuracy of the whole blood-lead test results were ascertained by comparison with known samples of Seronorm™ Trace Elements (SGAB AS-Whole blood L-2, Sero, Germany). Known sample containing added Seronorm™ Trace Elements, 0.5, 1.0 and 2.0 μg/dl, was used in determining the within-day accuracy and between-day precision of the method. The RSDs (100 x SD/mean) were calculated for 10 days for between-day precision. The accuracy of the overall method ranged from 84.4 to 86.3% and the calculated precision was within 8% RSD.

Mercury

For the preparation of urine samples, 2.00 mL of urine were mixed with 0.1 ml of 35% w/w nitric acid, 0.2 ml of 50% w/w sulfuric acid and 0.5 ml of 5% w/v potassium permanganate. The sample solution was allowed to stand at room temperature for 15 minutes. If the solution's color changed from purple to brown then a further 0.5 ml of permanganate solution was added, mixed, and allowed to stand for a further 15 minutes. This process of adding successive aliquots of permanganate solution and allowing the reaction to proceed was maintained until the purple color was sustained. With increasing masses of dissolved organic materials increasing volumes of permanganate solution are required. After the permanganate reaction is completed, then 0.4 ml of 2.5% (w/v) potassium persulfate was added and mixed. Incubate at 95°C for at least 2 hours and then let it cool down. 0.5 ml of 5% (w/v) hydroxylamine hydrochloride and 1 ml of 10% $SnCl_2$ solution are added with an accessory dispenser. The total volume is made up to 10.0 ml with reagent water and mixed well prior to determination. This method of urinary mercury determination was modified from that of Ham (1997)[14].

Calibration, recovery and reproducibility

Urine mercury was analyzed by CETAC M6000A cold-vapor atomic absorption spectrometer (CVAAS) mercury analyzer. Determination of urinary-mercury level was calibrated by preparing a series of standard additions to contain 0, 10, 20 and 40 μg/dl. The correlation coefficient (r) between the mercury concentration in the authentic mercury solution and absorption was 0.9999. The limit of detection (LOD) was 5 μg/g creatinine. BIO-RAD Lyphochek® Urine Metals Control (from Bio-Red, USA), was prepared from human urine with added mercury. 0.5, 1.5 and 2.0 μg/g creatinine, was used in determining the within-day accuracy and between-day precision of the method. The accuracy of the method ranged from 95.1 to 99.8% and the calculated precision was within 5% RSD.

The specimen samples in the present study were sent to the laboratory at Mahidol University, where heavy metals in bio-specimens can be analyzed. Whole blood-lead samples were analyzed by the Central Equipment Unit, Faculty of Tropical Medicine, Mahidol University. Urine mercury was analyzed by the Faculty of Medicine Technology, Mahidol University.

Statistical analysis

Descriptive statistics were used to display the heavy-metal concentrations results in whole blood and urine. The Mann-Whitney U test was used to compare the medians of continuous variables of the exposed and control groups. The Spearman's Rank Correlation test was used to test the association of independent factors with the heavy-metal concentrations in biological samples. The medians of data were compared using the Mann-Whitney U test for two groups or the Kruskal-Wallis test for more than two groups. A p-value of less than 0.05 was considered statistically significant.

Results

General characteristics of the subjects

Ninety subjects participated in the present study. Most subjects (35.6%) were aged between 20-30 years. All subjects were Buddhists. Most exposed subjects had primary and secondary education levels, while the control subjects had vocational-school education levels. More exposed subjects smoked cigarettes and drank alcoholic beverages than control subjects (Table 1).

Heavy metals in biological samples of nielloware workers

The average blood-lead and urinary-mercury levels of the exposed and control subjects were significantly different, at p-values of < 0.001 and < 0.001, respectively (Table 2). The blood-lead levels of the nielloware workers were below the 40-µg/dl[15] threshold recommended by the Occupational Safety and Health Administration (OSHA). The urinary-mercury levels were also below the 35 µg/g creatinine biological exposure index recommended by the American Conference of Governmental Industrial Hygienist (ACGIH) [16].

General characteristics and biological monitoring

Workers having incomes > 10,000 Baht per month had significantly higher blood-lead and urinary-mercury levels than those with incomes < 10,000 Baht, at p-values of < 0.001 and 0.020, respectively (Table 3).

Pearson correlation was used to determine the relationship between the nielloware workers' income and blood-lead and urinary-mercury levels. The correlation coefficients for the income and blood-lead levels were 0.968 (p < 0.001). Income and urinary-mercury level had a correlation coefficient of 0.661 (p = 0.004) (Table 4).

Working environment and biological monitoring

From observation and walk-through survey, 55.6% of nielloware workers worked in factories and 44.4% in houses. The blood-lead levels of workers in factories were significantly lower than those in houses (Table 5). For those working in houses, those who worked and lived in the same place had significantly higher blood-lead levels than those who did not. The urinary-mercury levels of workers showed a similar trend; a significant difference was found between those who worked and lived in the same area and those who did not. Different types of ventilation system did not show a significant difference in reducing the blood-lead or urinary-mercury levels of workers, except that one worker using a hood had the lowest blood-lead level (4 µg/dl). The temperature of the working environments ranged from 28 to 30°C.

Most workers (60%) worked > 8 hours per day and 37.8% worked seven days per week. Some of them (22.2%) started working when they were < 15 years old. They learnt from their parents and wanted to continue the family business. In the process of making nielloware, each worker was responsible for the whole process. Only specialists could make gold-encrusted nielloware. In the present study, only specialists were exposed to mercury. Specialists also had significantly higher blood-lead levels than assistants (Table 6). Both specialists and assistants who had worked > 5 years had significantly higher blood-lead and urinary-mercury levels than those who had worked < 5 years (p-values < 0.006, 0.021 and 0.003, respectively). For the three sizes of nielloware products, 57.8% of workers worked with large, 33.3% with medium and 8.9% with small.

Table 1. General characteristics of the exposed and control subjects (n = 90)

Parameter	Control subjects (n = 45)	Exposed subjects (n = 45)
Sex		
Male	27 (60.0%)	27 (60.0%)
Female	18 (40.0%)	18 (40.0%)
Age (years)		
20-30	16 (35.6%)	16 (35.6%)
> 30-40	14 (31.1%)	14 (31.1%)
> 40-50	12 (26.7%)	12 (26.7%)
> 50	3 (6.6%)	3 (6.6%)
Education level		
Primary school	1 (2.2%)	13 (29.0%)
Secondary school	7 (15.6%)	10 (22.2%)
Vocational school	20 (44.4%)	6 (13.3%)
Diploma or equivalent	9 (20.0%)	6 (13.3%)
Bachelor degree or higher	8 (17.8%)	10 (22.2%)
Marital status		
Single	9 (20%)	12 (26.7%)
Married	28 (62.2%)	26 (57.8%)
Widowed	7 (15.6%)	5 (11.1%)
Separated/Divorced	1 (2.2%)	2 (4.4%)
Income (Baht)		
≤ 10,000	21 (46.7%)	30 (66.67%)
> 10,000	24 (53.3%)	15 (33.33%)
Smoked cigarettes		
No	35 (77.8%)	17 (37.8%)
Yes	10 (22.2%)	28 (62.2%)
Alcohol consumption		
No	30 (66.7%)	16 (35.6%)
Yes	15 (33.3%)	29 (64.4%)

Table 2. Comparison of blood-lead and urinary-mercury levels in exposed and control subjects

Metal	Control subject	Exposed workers	p-value
Lead (μg/dl) (n = 45)			
Median	6.29	7.30	<0.001*
Interquartile range	2.58	7.36	
Mercury (μg/g creatinine) (n = 17)			
Median	0.10	3.30	<0.001*
Interquartile range	0.60	6.95	

* Significant at $p < 0.05$

Table 3. Comparison between general characteristics and biological monitoring of nielloware workers

Characteristic	Number of lead exposed workers	Median of Blood-lead (μg/dl)	Interquartile range	p-value	Number of mercury exposed workers	Median of urinary mercury (μg/g creatinine)	Interquartile range	p-value
Age (years)								
20-30	16	4.38	4.90	0.156	-	-	-	0.486
> 30-40	14	7.56	7.43		8	1.10	1.20	
> 40-50	12	11.53	13.35		7	6.30	5.60	
> 50	3	5.00	2.45		2	6.10	5.10	
Income/month (Baht)								
≤ 10,000	30	5.12	3.33	<0.001*	6	1.50	2.30	0.020*
> 10,000	15	17.16	12.07		11	6.40	15.00	

* Significant at $p < 0.05$

Table 4. Correlation coefficients between income and biological monitoring of nielloware workers

Variables	correlation coefficient	p-value
Income and blood-lead levels (n = 45)	0.968	<0.001*
Income and urinary-mercury levels (n = 17)	0.661	0.004*

* Significant at $p < 0.05$

Personal protective equipment (PPE) and biological monitoring

Most workers (73.3%) used cotton masks to protect themselves from dust and fumes, and most workers (64.4%) used gloves when applying niello or gold amalgam. Both specialists and assistants who used mask and/or gloves had significantly lower blood-lead and urinary-mercury levels than those who did not (Table 7).

Personal hygiene and biological monitoring

Most workers (66.7%) often ate snacks or drank water during work. Most workers (60%) washed their hands sometimes before eating snacks or drinking water. Sixty-seven percent of them washed their hands before lunch and 75.6% did so before dinner. Both specialists and assistants who always ate snacks had significantly higher blood-lead and urinary-mercury levels than those who sometimes did (Table 8). It was concluded that hand-washing can significantly reduce both blood-lead and urinary-mercury levels in specialist and assistant nielloware workers.

Acute and chronic neurological symptoms, and biological monitoring

Most non-exposed subjects reported no acute symptoms, four of them (8.9%) experienced

Table 5. Comparison between blood-lead and urinary-mercury levels and different working environments of nielloware workers

Parameter	Number of lead exposed workers	Median of blood-lead (µg/dl)	Interquartile range	p-value	Number of mercury exposed workers	Median of urinary mercury (µg/g creatinine)	Interquartile range	p-value
Type of the workplace								
House	20	13.88	9.96	<0.001*	14	5.90	10.00	0.432
Factory	25	5.00	2.70		3	1.90	2.10	
Working and living in the same area								
Yes	20	13.88	11.95	<0.001*	10	6.65	14.60	0.043*
No	25	6.00	3.41		7	1.60	2.20	
Ventilation systems used								
Natural ventilation	5	7.56	8.68	0.637	4	2.50	5.35	0.345
Hood	1	4.00	-		1	5.70	-	
Electric fan	19	6.95	6.59		9	8.15	6.93	
Combined natural ventilation and electric fan	20	7.10	9.08		3	2.45	7.88	

* Significant at $p < 0.05$

Table 6. Comparison of blood-lead and urinary-mercury levels, and working parameters of nielloware workers

Parameter	Number of lead exposed workers	Blood-lead Median (µg/dl)	Interquartile range	p-value	Number of mercury exposed workers	Urinary mercury Median (µg/g creatinine)	Interquartile range	p-value
Position								
Specialist	17	16.31	10.55	<0.001*	17	-	-	-
Assistant	28	5.00	2.85					
Duration of work (years)								
Specialist								
≤ 5	4	9.95	1.60	0.006*	4	0.70	1.23	0.003*
> 5	13	17.70	10.30		13	6.10	10.80	
Assistant								
≤ 5	11	4.00	1.00	0.021*				
> 5	17	6.50	2.43					
Product size								
Small	4	9.06	15.68	0.605	3	6.25	11.25	0.627
Medium	15	7.30	6.60		8	6.10	13.25	
Large	26	6.80	7.49		6	1.90	8.50	

* Significant at $p < 0.05$

Table 7. Comparison of blood-lead and urinary-mercury levels, and personal protective equipment used by nielloware workers

Positions	PPE used	Number of lead exposed workers (n = 45)	Blood-lead Median (µg/dl)	Interquartile range	p-value	Number of mercury exposed workers (n = 17)	Urinary mercury Median (µg/g creatinine)	Interquartile range	p-value
	Mask								
Specialists	Yes	12	7.00	4.10	0.002*	10	1.45	1.90	<0.001*
	No	5	18.35	11.18		7	9.40	10.60	
Assistants	Yes	21	4.00	1.60	0.003*				
	No	7	7.30	0.85					
	Glove								
Specialists	Yes	5	10.60	1.50	0.001*	12	1.75	4.15	<0.001*
	No	12	18.05	9.40		5	16.60	12.45	
Assistants	Yes	24	4.69	2.45	0.003*				
	No	4	8.08	1.69					

* Significant at $p < 0.05$

Table 8. Comparison of blood-lead and urinary-mercury levels, and personal hygiene of nielloware workers

Parameter/position	Parameter	Number of lead exposed workers (n = 45)	Blood-lead Median (µg/dl)	Interquartile range	p-value	Number of mercury exposed workers (n = 17)	Urinary mercury Median (µg/g creatinine)	Interquartile range	p-value
Ate snacks or drank water during work									
Specialists	Sometimes	2	4.00	0.19	0.024*	11	1.60	2.40	<0.001*
	Always	15	8.70	2.42		6	13.00	11.90	
Assistants	Sometimes	13	9.10	9.00	<0.001*				
	Always	15	17.20	12.10					
Wash hands before lunch									
Specialists	Sometimes	4	8.08	2.36	0.004*	7	9.40	10.60	<0.001*
	Always	13	4.69	2.60		10	1.45	1.90	
Assistants	Sometimes	11	18.40	9.40	0.001*				
	Always	17	10.60	1.40					

* Significant at $p < 0.05$

headaches. Among the exposed subjects, 46.7% reported headaches, 46.7% fatigue or arrhythmia, 35.6% rashes or dermatitis and 35.6% numbness in the extremities or paresthesis.

The blood-lead and urinary-mercury levels of subjects who reported and did not report acute symptoms were compared. The exposed workers who reported headache and fatigue had significantly higher blood-lead levels than those did not (p-values 0.014 and 0.013, respectively) (Table 9). Urinary-mercury levels showed the same trend. A significant difference was found for headache, rash, chest tightness, fatigue, and loss of consciousness (p-values < 0.001, < 0.001, 0.012, 0.024 and 0.025, respectively).

The common chronic neurological symptoms among nielloware workers were feelings of chest tightness (33.3%), short-term memory loss (31.1%) and perspiration (20%). The blood-lead and urinary-mercury levels of the subjects reporting and not reporting chronic symptoms were compared. Those reporting abnormal tiredness had significantly higher blood-lead and urinary-mercury levels than those who did not (p-values = 0.030 and < 0.001, respectively). The workers reporting headache at least once a week had significantly higher urinary-mercury levels than those not reporting headache (p-value 0.002) (Table 10).

Discussion

Heavy-metal levels

Blood-lead and urinary-mercury levels are commonly used as indicators and diagnostic measures for heavy-metal exposure in humans[16]. The results of the present study showed that the blood-lead and urinary-mercury levels in these nielloware workers were higher than matched control subjects. Among the nielloware workers in the present study, the average blood-lead and urinary-mercury levels were 9.69 ± 6.72 μg/dl (range 4.0-27.7 μg/dl) and 6.18 ± 6.85 μg/g creatinine (range 0.1-23.7 μg/g creatinine), respectively.

All nielloware workers had blood-lead levels < 40 μg/dl[15], the minimum level of concern by OSHA, USA, 60 μg/dl[17] recommended by the Ministry of Public Health, Thailand. However, functional neurological and systemic disorders were identified at low levels of lead exposure, *i.e.* 20 μg/dl of blood-lead level[18]. All nielloware workers had urinary-mercury levels < 35-μg/g creatinine[16], the ACGIH-recommended biological exposure index for mercury in urine.

The results indicated that occupational heavy-metal exposure could pose significant health risks among nielloware workers. Thus, health surveillance of nielloware workers should be monitored. They should have regular physical check-ups and medical examinations. The health education about toxicity of heavy metals, working condition improvement, personal hygiene and personal protective equipment used should be carried out in this group of workers.

Specialist workers had higher blood-lead levels than assistant workers because the specialists also applied the niello amalgam on the surface of the objects apart from the main activities. Specialist workers are exposed to mercury vapor during the application of gold amalgam to the nielloware products. The average urinary-mercury levels of the specialist workers were significantly higher than the control subjects.

Factors associated with heavy-metal levels

A recent study found many factors influence the increase of blood-lead and urinary-mercury levels. The present study found that different work position (such as that of specialist) and different work durations resulted in significantly different median heavy-metal levels, as well. Specialists could be exposed with heavy metals more often than assistants, because of their higher ordered products, so that their contamination with heavy metals would be greater than the assistants. The result of the present study was similar to that of Thanapop et al[19], the mean blood-lead levels of Thai boatyard workers differed by job type. Chuang et al[20] reported that the mean blood-lead levels differed by job type among lead-battery workers in Taiwan.

With regards to working duration, it was found that median heavy-metal levels differed significantly; both specialists and assistants who worked > 5 years had significantly higher heavy-metal levels than those who worked < 5 years. This may be due to long-term exposure of workers to lead and mercury, leading to accumulation of these metals in the bodies due to a lack of appropriate prevention measures[3]. The present study agrees with Lormphongs et al[21], who reported slightly higher blood-lead levels of workers working for 20-29 years than those working for $\leq$ 19 years.

Workers earning different incomes had significantly different blood-lead and urinary-mercury levels, as well. This may be because some were freelance, and were able to get more product orders. Thus, each nielloware worker would have a different

Table 9. Comparison between blood-lead and urinary-mercury levels, and reported acute symptoms of nielloware workers

Acute symptoms	Number of lead exposed workers	Median of blood-lead (µg/dl)	Interquartile range	p-value	Number of mercury exposed workers	Median of urinary mercury (µg/g creatinine)	Interquartile range	p-value
Headaches								
No	24	5.62	5.13	0.014*	7	1.10	1.10	<0.001*
Yes	21	10.58	11.52		10	6.65	11.60	
Rashes								
No	29	6.70	6.57	0.148	5	0.90	0.90	<0.001*
Yes	16	8.95	11.26		12	6.25	12.10	
Tightness in the chest								
No	31	6.70	5.30	0.056	3	0.90	0.70	0.012*
Yes	14	12.91	12.85		14	5.90	9.38	
Fatigue								
No	24	5.62	5.20	0.013*	2	0.30	0.60	0.024*
Yes	21	10.56	11.23		15	5.70	7.80	
Loss of consciousness								
No	7	6.29	3.40	0.134	15	2.50	5.30	0.025*
Yes	38	7.49	10.67		2	20.35	15.05	

* Significant at $p < 0.05$

Table 10. Comparison of blood-lead and urinary-mercury levels, and reported chronic symptoms of nielloware workers

Neurological symptoms	Number of lead exposed workers	Median of blood-lead (µg/dl)	Interquartile range	p-value	Number of mercury exposed workers	Median of urinary mercury (µg/g creatinine)	Interquartile range	p-value
Abnormal tiredness								
No	9	6.80	6.56	0.030*	8	1.20	1.23	<0.001*
Yes	36	15.25	14.33		9	6.90	10.90	
Feels oppression in chest								
No	15	6.60	6.56	0.133	2	0.60	1.20	0.053
Yes	30	8.60	11.68		15	5.70	7.80	
Experiences headache at least once a week								
No	7	6.80	6.59	0.256	12	1.75	4.15	0.002*
Yes	38	7.40	11.16		5	16.60	12.45	

* Significant at $p < 0.05$

income and their contact with lead and mercury would differ.

Neilloware workers were considered as informal workers; some of them used their houses as their workplaces. They worked and lived in the same area because their house was not big enough to separate the working and living areas. That is why contamination of metals in their houses led to higher levels of metals in their bodies. Some of them were employed to work in factory; their workplaces and living areas are separated leading to low levels of metals in their bodies.

Behavioral factors were also found to be associated with blood heavy-metal levels. Observations of work areas found heavy-metal contamination of hands, clothes, hand-tools and work surfaces. Both specialists and assistants who ate snacks or drank water while working had significantly higher heavy-metal levels than those who sometimes did. Eating and drinking while working can result in metal contamination and various diseases, because the workers do not clean their hands. This is also supported by Karita K et al[22], who reported the mean blood-lead level in 28 anode workers who ate snacks between meals during working hours was significantly higher than three non-eating workers. Both specialists and assistant nielloware workers who did not wash their hands before lunch had significantly higher heavy-metal levels than those who did. This result is also supported by Berode et al. and Mahaffey et al[23,24], who reported exposure by ingestion from contaminated clothes and hands. Thus, the safety behaviors of nielloware workers, including personal hygiene, should be strengthened.

Self-protection while working can help prevent contamination. Both specialists and assistants who used PPE (mask and/or gloves) had significantly lower heavy-metal levels than those who did not. This was consistent with the concept of behavioral change for safety. Self-protection of workers from hazardous materials is important. This result is supported by Rogers[25]. Their risk of exposure to hazardous materials will be decreased by recommended appropriate behaviors.

Acute symptoms, including headache and fatigue, were significantly higher among those with higher blood-lead levels. Abnormal tiredness was significantly higher among those with higher blood-lead levels. The present study differs from Fischbein et al[26], who studied average blood-leads and zinc protoporphyrin levels among 90 cable splicers, with and without neurological (CNS, *i.e.*, headache, fatigue, dizziness, loss of consciousness) or gastrointestinal symptoms (GI *i.e.*, metallic, nausea, abdominal discomfort, pain, lead colic); 37% gave a history of CNS and GI symptoms, 12 reported both CNS and GI symptoms, 14 CNS symptoms alone and seven GI symptoms alone. Those who reported CNS and GI symptoms did not have significant difference of blood-lead levels, but zinc protoporphyrin levels differed significantly. Thus, blood ZPP level is a more sensitive indicator for the effects of lead on the body than other parameters, such as blood lead and urinary lead. Headache, rash, chest tightness, fatigue and loss of consciousness were significantly higher among those with elevated urinary-mercury levels. These results are similar to the study by Susan et al[9], who classified the physical-examination symptoms of jewelers.

In addition, abnormal tiredness and headache at least once per week were significantly higher among those with elevated urinary-mercury levels. Thus, workers chronically exposed to heavy metals are at increased risk of developing neurological symptoms.

In summary, heavy-metal contamination in the workplace should be investigated regularly, with annual health surveillance to evaluate the effectiveness of control measures in the workplace and to protect the health of workers. For those working in their homes, health education would help them to realize the toxicity of metals and they may try harder to protect themselves and their families. Personal protective equipment, mask and gloves could help reduce exposure of heavy metals in nielloware workers.

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Potential conflicts of interest

None.

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การตรวจวัดโลหะหนักในตัวอย่างชีวภาพในคนงานทำเครื่องถม ในจังหวัดนครศรีธรรมราช

โสมศิริ เดชารัตน์, ประพิน ธารภูผาสยาม, พรพิมล กองทิพย์, พิชญา พรรคทองสุข, สุวลีย์ วรคุณพิเศษ, อนามัย เทศกะทึก

วัตถุประสงค์: *เพื่อตรวจวัดระดับโลหะหนักในเลือดและปัสสาวะในคนงานทำเครื่องถม และอธิบายความสัมพันธ์กับข้อมูลการทำงาน ตำแหน่งงาน สภาพแวดล้อมการทำงาน ปัจจัยด้านพฤติกรรม และสำรวจอาการเฉียบพลันและอาการเรื้อรังทางระบบประสาท*

วัสดุและวิธีการ: *เป็นการสำรวจภาคตัดขวางโดยการสัมภาษณ์ด้วยแบบสอบถามในคนงานทำเครื่องถมจำนวน 45 คน และ 45 คน ในกลุ่มควบคุมที่อาศัยในเขตเทศบาลนคร จังหวัดนครศรีธรรมราช ประเทศไทย ตะกั่วในเลือดและปรอทในปัสสาวะจะถูกวิเคราะห์หาโลหะหนักโดยเครื่องอะตอมมิค แอบซอฟชัน สเปกโตโฟโตมิเตอร์*

ผลการศึกษา: *ระดับตะกั่วในเลือด (7.30 ไมโครกรัมต่อเดซิลิตร)และปรอทในปัสสาวะ(3.30ไมโครกรัมต่อกรัมคริตินิน) ของคนงานทำเครื่องถมมีระดับสูงกว่ากลุ่มควบคุม ($p < 0.001$) รายได้ สภาพแวดล้อมการทำงาน ตำแหน่ง ระยะเวลาการทำงาน การใช้อุปกรณ์คุ้มครองส่วนบุคคล และสุขวิทยาส่วนบุคคลมีความสัมพันธ์กับระดับตะกั่วในเลือดและปรอทในปัสสาวะ $p < 0.05$ พบความสัมพันธ์เชิงบวกระหว่างรายได้กับระดับตะกั่วในเลือด ($r = 0.968$, $p < 0.001$) และปรอทในปัสสาวะ ($r = 0.661$, $p = 0.004$) คนงานทำเครื่องถมมีอาการเฉียบพลันและเรื้อรัง ได้แก่ ปวดศีรษะ ผื่นคัน เหนื่อย แน่นหน้าอก หมดสติ เหนื่อยง่าย และปวดศีรษะบ่อยครั้ง อาการดังกล่าวจะเกิดขึ้นกับคนงานที่มีระดับของโลหะหนักสูงกว่า $p < 0.05$*

สรุป: *ระดับตะกั่วในเลือดและปรอทในปัสสาวะในกลุ่มคนงานทำเครื่องถมมีระดับสูงกว่ากลุ่มควบคุม พบความสัมพันธ์ระหว่าง รายได้ ตำแหน่งงาน การใช้อุปกรณ์คุ้มครองส่วนบุคคล และสุขวิทยาส่วนบุคคล และระดับตะกั่วในเลือดและปรอทในปัสสาวะ*