PLACER SMALL-SCALE GOLD MINING AND OCCUPATIONAL EXPOSURE TO HEAVY METALS IN SOIL IN MYANMAR

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Abstract - Heavy metal exposure is one of the serious health issues worldwide. In Myanmar, there are many local gold mining sites where many miners are exposed to heavy metals and may receive adverse health effects through mining processes. This study investigates the steps in placer gold mining of local mining sites in Banmauk Township, Myanmar. In addition, the exposure to heavy metals in the soil from each placer gold mining step was also evaluated: ore processing, sluicing, panning and amalgamation. A questionnaire and observations were used to explore the processes involved in local placer gold mining and identify the exposed body parts to heavy metals. The results showed that the percentages for each exposed body part of the miners were 100% for forearms, hands and feet, 94% for lowers legs, and 13% for the whole body. In addition, most of the body parts of the miners were exposed to heavy metals in the soil during ore processing. Furthermore, approximately 79% of the participants in this study had never used any form of personal protective equipment (PPE) while working. The resulting data on placer gold mining processes and the exposure percentages of body to heavy metals in the mining soil can be used in the future to create a database on occupational risks in Myanmar.

Keywords - Exposure to Soil, Heavy Metals, Mining, Myanmar

I. INTRODUCTION

Artisanal and small-scale gold mining (ASGM) provides 20 to 30 percent of the total gold production of the world [1]; however, its activities are generally carried out in risky conditions. It is normally conducted by using simple tools and methods for gold extraction, as ASGM miners normally have less financial backing, poor health and safety protection, and limited mining experience [2]. In ASGM processes, most miners extensively use mercury (Hg) to amalgamate gold, thereby discharging mercury into the atmosphere, soil, and water [3]. ASGM has, therefore, been reported as the world's largest mercury production and anthropogenic source of mercury released into the environment [4]. Moreover, gold mining activities can increase the level of naturally occurring heavy metals such as arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb) in the environment. As a result, this can lead to the pollution of water, soil, and sediment, and adverse human health effects such as carcinogenic and non-carcinogenic diseases to human, e.g. skin tumors, muscular pain, rashes etc., [5]-[10]. As, Cd, Hg, Pb, zinc (Zn), and copper (Cu) are mostly found in gold mining areas [11], [12]. Among these heavy metals, As, Cd, Hg and Pb have been identified as class 1 elemental impurities based on their toxicity to humans and animals, in terms of their carcinogenicity and likelihood of occurrence [13], [14]. In Myanmar, gold mining activities are being conducted throughout the whole country, and the majority of the gold mining areas are in the Kachin State, Sagaing Region, Mandalay Region, and Bago Region [15]. Myanmar's gold production was 1,692 kg in December 2015 and of 1,700 kg in December 2016 [16]. Between large-scale and artisanal and small-scale gold mining (ASGM), ASGM is commonly found in Myanmar [17]. ASGM in Myanmar was classified as Kone-Myaw means "washing on land" and Ye-Myaw, which means "washing in the river" [15]. Ye-Myaw, in which sluicing is conducted in the river by using a gold mining boat, is only carried out by some artisanal gold miners, while most artisanal miners are conducting Kone-Myaw, in which sluicing is conducted on land. Small-scale gold mining is commonly implemented through open-pit mining (surface mining) where rocks or minerals from an open-pit in the ground or underground are extracted to mine ore through tunnels or shafts. Open-pit mining through the placer gold mining technique is common for small-scale gold miners in Myanmar.

Although gold mining activities are being widely conducted all over the country, there is little research regarding the impacts of gold mining activities on human health. Research is necessary to understand the impacts of gold mining activities on miners' occupational health risks. Therefore, this study attempted to identify the local gold mining processes that might have the greatest adverse health effects on miners. The study was conducted at three small-scale gold mining sites that used the placer gold mining technique in Banmauk Township, which is one of the main small-scale gold mining areas in the Sagaing Region of Myanmar. The aim of this study was to

determine the occupational exposure to heavy metals in the soil and the body parts of the exposed miners during placer gold mining processes.

II. PLACER SMALL-SCALE GOLD MINING IN MYANMAR

In Myanmar, the placer gold mining method mainly involves extracting the material, ore processing, sluicing, panning, amalgamation and the burning of the amalgam.

A. Extraction of Material

In the step of extraction of material, alluvial deposits or hard-rock deposits are exploited by excavating the surface soil or overburden [18]. In the study sites, machines like backhoes are mainly used to dig and remove the overburden (Fig. 2a), and miners just need to control the machine to remove the top soil over gold-containing placer deposits (ore). After removing the top soil, the placer deposits are mined by backhoes and then carried and piled by dump trucks in a place for conducting the next step of processing the ore.

B. Ore Processing

Ore processing is liberating the gold from other minerals by forming slurries through adding water into placer deposits [18], [19]. In this step, miners have to wash out ore deposits to form slurries by using high-pressure nozzle heads (Fig. 2b) and have to dredge up the ore slurries onto the sluices by using a pumping machine simultaneously (Fig. 2c).

C. Sluicing

The sluicing step is continuously carried out with the step of ore processing (Fig. 2d). Sluices used in this step are made by bamboo or wood, and the sizes of the sluices range from 0.5-2 m in width and 1-15 m in length. And then, waterproof carpets are put onto the sluices in order to catch the gold particles while the slurries are going down along the sluices due to the higher density of gold than other materials [20]. After dredging up the ore like slurries onto the sluices for some time, the carpets on the sluices become full of gold-containing soil, and some soil falls down along the sluices in the form of slurry. After that, the miners collect the carpets that are full of gold-containing soil and then change the new ones. Afterwards, the collected carpets are washed in the tanks and the tanks are carried into a pond to conduct the panning step.

D. Panning

Panning is then conducted in a pond, where the tanks from the sluicing step are placed, by using wooden or metal pans to recover gold from the soil (Fig. 2e). In this step, gold-containing soil from the tanks are put into a pan, and then gold particles are made to aggregate at the bottom of the pan by hand-shaking the pan. After that, some of the soil that does not contain gold particles is then removed from the pan into the pond. Consequently, less amount of soil mixed with gold particles is obtained in the pan, and the gold-containing soil is then collected and placed into other tanks. Finally, the tanks are carried again to another pond for amalgamation step.

E. Amalgamation

The fourth step called amalgamation is conducted to recover gold particles from the soil by adding mercury (Fig. 2f). In this step, miners also use the pans, and gold-containing soil from the tanks obtained from the panning step are put into a pan and then mercury is mixed with the soil by hand in the pan. And then, the pan is shaken by hand in the small pond, like in the panning step. Consequently, mercury adheres onto the surface of gold particles due to the higher surface tension of gold than that of mercury [19]. After that, gold particles mixed with mercury aggregate at the bottom of the pan by separating from the soil and the soil is then thrown into the pond. And then, the mixture of gold particles and mercury is put into a cloth bag and squeezed by hand; as a result, some mercury is directly released into the pond, soil or pan. Finally, gold particles mixed with some mercury, called an amalgam, are obtained in the cloth bag. After completion of this step, the soil in the pond is taken and piled beside the pond in order to reuse this soil again for amalgamation.

F. Burning of the Amalgam

After the amalgamation step, the final step, called burning of the amalgam, is carried out to recover the gold from the mercury by evaporating the mercury through heating. Two main approaches of burning the amalgam: open burning (Fig. 2g) and burning the amalgam with a mercury capture system (Fig. 2h) were adopted in Myanmar and in the study sites as well.



In the open burning, amalgam is directly heated and all the mercury is emitted into the atmosphere, whereas the second approach burns the amalgam inside a vapor capture system such as mercury capture device [15]. This step is generally conducted in a specified room or place near the office of the site manager that is away from slurries in order to prevent from gold losing.

Fig. 2 Placer small-scale gold mining in Banmauk Township: (a) Removing surface soil by using backhoe and truck. (b) Hydraulic mining with high-pressure nozzle head pump. (c) Dredging up the ore slurries through pumping machine. (d) Sluicing through wooden sluice. (e) Panning by using wooden pan. (f) Recovering gold particles from the soil through amalgamation with mercury. (g) Burning of the amalgam through opening burning. (h) Burning of the amalgam through vapor capture system.

III. MATERIALS AND METHODS

A. Study Area

This study was conducted in three placer small-scale gold mining sites, Site A, Site B and Site C in Banmauk Township, Sagaing Region, Myanmar. Site A is located within the Hmawbon public protected forest, which has an area of 122.65 km^2, and Site B and Site C are located in the Nant Kyin forest reserve, which has an area of 182.78 km^2. The areas of Site A, Site B and Site C are 0.081 km2, 0.081 km^2 and 0.055 km^2, respectively. These mining sites are situated about 46.7 km north-east of Banmauk Town. Banmauk Township is one of the main gold mining areas in the Sagaing Region of Myanmar. In Banmauk Township, both legal and illegal gold mining activities can be found because of the wide occurrence of placer deposits in this area, but research papers on the impacts of mining activities in this area are very limited. Placer deposits, which are very common for artisanal and small-scale miners due to its easy access, can also be extensively found in the vicinity of the study area.



Fig. 1 Map of the study area

B. Participants and Data Collection

This study, conducted in January 2019, was a cross-sectional study that made use of observations and a questionnaire for face-to-face interviews to explore the information of the miners and gold-mining processes at the three placer small-scale gold mining sites. This study has already been approved by the Ethic Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University.

The target group in this study was made up of both male and female placer small-scale gold miners within the age range of 18-60 years who worked in the gold mining steps of ore processing, sluicing, panning and/or amalgamation. In addition, they must have at least worked for 12 months at the study sites. A total of 53 miners were recruited as participants: 19 participants from site A, 17 participants from site B, and 17 participants from site C. Face-to-face interviews were used to structure a database about their personal information, socio-demographic, and working behavior in each step of the gold mining process. The descriptive data analysis by Microsoft Excel® was used to analyze the data collected through questionnaire.

IV. RESULTS AND DISCUSSION

A.Characteristics of Small-scale Gold Miners

In this study, the 53 participants from the three placer small-scale gold mining sites were asked the interview questions face-to-face. The results show that the ages of the gold miners in this study ranged from 18 to 55 years old, the median was 23 years of age and the mean age (±SD) was 23.70 (±6.5) years. The ages of the male participants range from 18 to 37 years old with a mean age (±SD) of 22.40 (±4.6) years, whereas the ages of female participants ranged from 18 to 55 years and the mean age (± SD) of 28.50 (±9.6) years. Body mass indexes (BMI) of the 49 participants were in the normal range (18.5-24.9), and just 2 male participants and 2 female participants were in the range of being overweight (25-29.9).

With regard to their education level, 2% of male participants had lower than a primary school education, 29% attended to primary school, 52% attended secondary school and 17% attended high school. For female participants, 36% received primary school education, 36% had gone to secondary school, and 28% had gone to high school. Among the 42 male participants, 43% were smokers and 57% were drinkers, whereas none of the female participants reported being smokers or drinkers. In terms of their marital status, 86% of the male and 82% of the female participants were single; 14% of the males and 9% of females were married; and 9% of female participants were widowed. The salary of the participants ranged from 100,000 kyats (65 USD) per month to 400,000 kyats (262 USD) per month, and the average (± SD)

monthly salary of the participants was 148113 (± 40003) kyats (97 ± 26 USD) with a median of 150000 kyats (98 USD). The salaries of the participants varied depending on their work experience and skill level. It is reported that the average monthly salary in Myanmar for all jobs in 2019 range from 74, 319 kyats (49 USD) to 2,431,379 kyats (1591 USD), and about 50% of the people earn 543, 583 kyats (356 USD) or less per month and about 25% of the people earn 278,056 kyats (182 USD) or less per month [21]. Therefore, the average monthly salary of the participants in this study was just in the range of the average monthly salary for 25% of the people in Myanmar (74,319 kyats (141 USD) to 278,056 kyats (182 USD)). However, the amount of average monthly salary of the participants was reportedly enough motivation to them to keep working at the mines because it is more than the minimum daily wage 4800 kyats (3 USD) in Myanmar [22]. All the above exchange of Myanmar Kyat against U.S. Dollar was estimated through [23].

Among the 53 participants in this study, 25 (47%) participants worked in the ore processing step called hydraulic mining and dredging; 14 (27%) participants worked in the sluicing step; 8 (15%) participants worked in the panning step; and 6 (11%) participants worked in the amalgamation step. However, the owners of the mining sites normally manipulate the number of miners depending on the availability of gold, and the highest numbers of miners are generally used for the ore processing step followed by sluicing step. The miners in this study have to work 8 hours per day and 6 days a week on average. Details of the socio-demographic characteristics of the miners were shown in Table I.

Table I Socio-demographic characteristics of the miners

Characteristics	Percentage % (n)	
	Male (n=42)	Female(n=11)
Age (Years)		
Range	18 to 37	18 to 55
Median	23	26
Mean (± SD)	22.40 (± 4.6)	28.50 (± 9.6)
Body Mass Index		
Normal(18.5-24.9)	95% (40)	82% (9)
Overweight(25-29.9)	5% (2)	18% (2)
Educational Level		
Lower than primary school	2% (1)	*
Primary school	29% (12)	36% (4)
Secondary school	52% (22)	36% (4)
High school	17% (7)	28% (3)
Smoking Behavior		
Smoker	43% (18)	*
Non-smoker	57% (24)	100% (11)
Drinking Behavior		
Drinker	57% (24)	*
Non-drinker	43% (18)	100% (11)
Marital Status		
Single	86% (36)	82% (9)
Married	14% (6)	9% (1)
Widowed	*	9% (1)
Income (USD)		
Range	65 to 262	65 to 98
Median	98	65
Mean (± SD)	102 (± 26)	77 (± 16)
Job Responsibilities		
Processing the ore	60% (25)	*
Sluicing	33% (14)	*
Panning	2% (1)	64% (7)
Amalgamation	5% (2)	36% (4)
Work Duration		
Hours per day		
Range	1 to 24	5 to 8
Median	8	8
Mean (± SD)	8.21 (± 2.69)	7.45 (± 1.16)
Days per week		

Characteristics	Percentage % (n)	
	Male (n=42)	Female(n=11)
Range	4 to 7	7
Median	7	7
Mean (± SD)	6 (± 1)	7 (± 0)

* No participant was investigated.

B. Exposed Body Parts and Personal Protective Equipment (PPE) Use Behaviors of the Miners

Vulnerability of the exposed body parts varies with the gold mining steps. In the extraction step, the miners have very less potential to be exposed to the heavy metals in the soil because this step requires machines instead of manual labor. In ore processing, the miners frequently work in the soil or slurries during hydraulic mining and dredging. Moreover, the soil and slurries can also splash on them even if they are adding water to the ore away from the slurries. In the sluicing step, miners were exposed to the soil during collection and changing of the waterproof carpets on the sluices. During panning and amalgamation, miners were exposed to the soil from the pans and pond while they are recovering gold particles from the ore by using pans. Also, during amalgam burning, the miners were mainly exposed to mercury vapor through inhalation, while they have less potential to be exposed to the soil. In brief, the miners have high potential to be exposed to heavy metals in the soil during ore processing, sluicing, panning and amalgamation respectively.

Furthermore, the results from the interview showed that all of the 25 participants (100%) were exposed to soil on their forearms, hands, lower legs and feet, and 5 participants (20%) were exposed to the soil on their whole body in the ore processing step. Likewise, in the sluicing step, all of the 14 participants (100%) were exposed to the soil on their forearms, hands, lower legs and feet, and 2 participants (14%) in this step were exposed to the soil on their whole body. In the panning step, all of the 8 participants (100%) were exposed to the soil on their forearms, hands, lower legs and feet; however, there was no participant who was exposed to the soil on their whole body. In the case of the amalgamation step, all 6 participants (100%) were exposed to the soil on their forearms, hands and feet, and 3 participants (50%) were exposed to the soil on their lower legs. Exposure to the soil with the whole body of the miners was not found in this step, like in panning step. Fig. 3 presented the percentages of the miners for exposure to soil through their body parts during working in the gold mining steps.

All in all, among the 53 participants, 100% of the participants were exposed to the soil on their forearms, hands and feet; 94% of the participants were exposed to the soil on their lower legs; and 13% were exposed to the soil on their whole body. Although they were exposed to the soil through their body parts during their work, 42 participants (79%) did not wear any personal protective equipment while they are conducting mining activities. Only 5 participants (9%) wore hand-length fabric gloves; 4 participants (8%) wore hand-length rubber gloves; and 3 participants (6%) wore mid-length rubber boots, of which one participant wore both hand-length rubber gloves and mid-length rubber boots. However, some participants, including those who did not wear any PPE, wore full trousers (27 participants (51%)), knee-length pants (9 participants (17%)), long-sleeves shirts (46 participants (87%)), elbow-length shirts (4 participants (8%)), and shorter-than-elbow-length shirts (1 participant (2%)). Fig. 4 showed PPE use behavior of the miners.

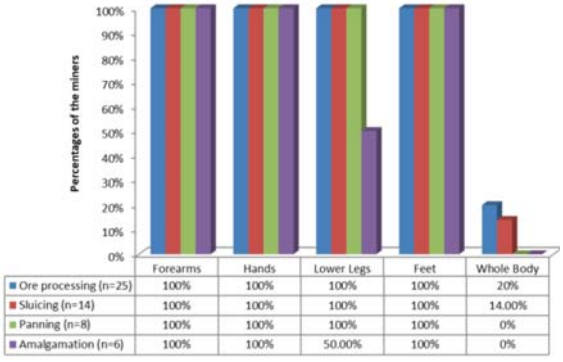


Fig. 3 Percentages of the miners' exposure through various body parts from four gold mining steps

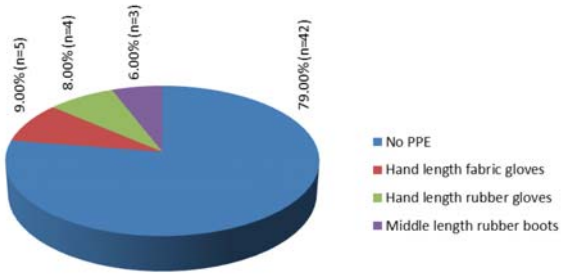


Fig. 4 PPE-use behavior of the miners

CONCLUSION

Among the steps ofplacer small-scale gold mining processes in Myanmar, the steps of ore processing, sluicing, panning, and amalgamation have higher potentials of exposing the workers to heavy metals in the soil. Furthermore, most of the body parts of the miners were exposed to the soil during working especially in the step of ore processing and sluicing. The results also indicated that the most exposed body parts of the miners were their forearms (100% of the

participants), hands (100% of the participants), lower legs (94% of the participants), and feet (100% of the participants). However, a few miners were exposed to the soil on their whole body (13% of the participants) while working. Although the miners were exposed to the soil on their body parts, 79% of the participants in this study did not wear any personal protective equipment while working. Therefore, health promotion about the importance of PPE is recommended for the miners especially at all steps of the placer gold mining processes. Furthermore, health risk assessments of miners should be performed in the future due to their occupational exposure to heavy metals from gold mining.

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