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# Safety and environmental hazard investigation of small scale mining in Benguet

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## ABSTRACT

The study looks into the safety and environmental hazards in small scale mining in Benguet, Philippines which is one of the largest mining areas in the country. Questionnaire-guided interviews and work analysis observation tool covering mining practices and risk exposures of miners were conducted. Results of the study showed that wearing of proper protective equipment among the miners was not observed. Unsafe conditions were also identified such as risk of fall during erection and dismantling of scaffolds, guard rails were not provided in scaffoldings, manual extraction of underground ores, use of explosives, poor visibility in looking for ores to take out to surface, exposure to noise from explosives, and to dust from the demolished structures. There was no proper ventilation for chemical exposures. Wastes were drained into soil or ground and/or rivers and streams. The most common health problems among miners were hypertension (62%), followed by hypertensive cardiovascular disease due to left wall ischemia (14%). Health injuries of the respondents noted were due to accidents such as secondary blasting, and stone crushing. Health symptoms such as headache, dermatitis, and peripheral neuropathy were noted and these can be considered as manifestations of chronic cyanide poisoning, further, aggravated by improper use of protective equipments. There is a need to establish programs on miners' occupational and environmental health and safety.


## KEYWORDS

Small scale mining;
Safety practices;
Occupational health and safety;
Environmental hazards;
Mining underground tunnels;
Gold mining;
Artisanal mining.

## INTRODUCTION

The mining sector contributes an essential part in the socio-economic development of many countries such that it creates employment/job opportunities and increases foreign currency earnings[20]. However, the mining sector brings with it negative impacts on environmental and human health[1]. Mining operations and associated processes involve the use of tools, equipments, and chemicals that are considered harmful to health and the environment. According to International Labor Organization[16], mining sector accounts the most of morbidities and mortalities in the informal sector in view of the fact that mining operations and associated processes employ the use of equipments, and chemicals that are dangerous to health and the environment.

According to Hentschel et. al.[11], small scale mining (SSM) or artisanal mining (ASM) is categorized under the informal sector of the market which has no or minimal mechanization or engineering techniques involved.). It involves rudimentary and conventional tools and techniques in exploration and drilling[13,34]. Individuals, groups and families are often the key players in the small scale mining. The operations involve marginal or small deposits, lack capital, are labor intensive, have poor access to market and support services, low standards of health and safety, and have a significant impact on the environment[21]. IIED[15] asserted that informal mining lacks environmental management, technical assistance, transfer and technological development, access to health system and job security, access to information and participation, and knowledge regarding humane working conditions. Moreover, ILO[16] noted that small scale mining recorded six or seven times higher non-fatal accidents than in larger operations, and largely contributes to environmental pollution as it utilizes dangerous chemicals such as mercury and cyanide in its processes.

Small scale mining can be a reflection of the social and economic status of a community's poverty. Telmer and Viega,[32] noted that artisanal small scale mining is a poverty driven source of livelihood in many countries. Workers employed are said to be the poorest and most marginalized in the society[7,24,27] and the only means of livelihood in rural communities due to limited economic resources or alternatives[10]. Since informal mining is equated as illegally operating mining activity, taxes or holding permits and/or formal title are not applied[31]. As such, small scale mining lacks government support.

One of the chemicals used in mining operations is cyanide. Cyanide has been used worldwide in the extraction of gold and silver. It is also used as a flotation reagent to recover other metals such as copper, lead, and zinc[6,36]. Cyanide remains as the most economical means of gold extraction. It quickly degrades into other non-toxic substances; not necessarily a poison; ubiquitous in nature in a non-toxic state. However, when cyanide creates a bond with other chemicals, it may be converted to very toxic and lethal compounds that may cause adverse impacts to health and the environment[18].

The United Nations Environmental Program (UNEP)[38], along with the study of Veiga et. al.,[35] noted that small-scale artisanal mining accounted for 20% to 30% of the world gold global production. Based on the Philippine record on small scale mining, there are about 185,000 workers that cater at least to 20,000 formal and informal businesses[11]. From the year 1990 to 1999, it has contributed to 40-50% of the country's total gold production[8].

In view of this, the study aims to investigate safety and occupational hazards of small scale miners in Benguet. This includes (1) the occupational related diseases/illnesses and (2) occupational safety practices of the miners. It is important to assess the workers' knowledge and views on mining so to be able to assess the need for occupational health and safety programs in the community and lessen the risk to occupational hazards. Leung[19] noted that it is important to study the occupational and environmental issues of mining as it plays a significant role in the Philippine economy.

## METHODOLOGY

### Study area/population

The target population consisted of small scale industries in Benguet. This focused on determination and description of occupational hazards affecting miners. Cross sectional design was used. Based on the records of the Small Scale Mining Association in Benguet (SSMAB), there are about 100 registered small scale mining industries in the area. Based on this, the sample size calculation is shown below:

$$n = \frac{NZ^2 \times p\,(1-p)}{Nd^2 + Z^2.p\,(1-p)}$$

Z= the value of the normal variable for a reliability level; this was set at 90 % reliability in this study considering budget and feasibility; p=.50 (the proportion of getting a positive sample for occupational hazards); 1-p=.50 (the proportion of getting a negative sample for occupational hazards)*; d= sampling error, set at.1; N= population size *, 100 based on available data in Benguet; n= sample size; Therefore:

$$n = \frac{100\,(1.645)^2 \times 0.5\,(0.5)}{100\,(0.1)^2 + (1.645)^2\,.0.5\,(0.5)}$$

n= 40- total industries

*The proportion of getting a positive sample in previous studies are variable. Hence, based on Bautista (2000), setting the *p* value at 0.50 is the standard level.

## Sampling frame

Based on the above, was a total of 40 small scale industries taken for the safety and occupational hazard investigation. The sampling frame consisted of the list of small scale mining industries. The samples were randomly selected (simple random sample) from the sampling frame. There was no strata since the study considers one group- small scale mining industries.

## Data collection and analysis

Data collection came in the form of safety and occupational hazard investigation of the work areas, as well as the use of survey questionnaires. The safety investigation and occupational hazard forms were used which considered factors such as safety of tunnels, materials that tunnels are made of, risk of caving in, ladders used, tools in digging and excavating, chemicals used in extraction of gold ores, use of personal protective equipment, ventilation system, alarm systems, among others. Data encoding and analysis was done using SPSS13.0.

# RESULTS

There was a total of 40 small scale mining industries that were investigated. A total of 89 male respondents were interviewed from these 40 industries. All were small scale miners. Fifty-eight of them were from Itogon, and 42% were from Tuba. The most common type of chemical the miners used was cyanide, particularly sodium cyanide.

The average annual production of gold was 1,259.53 grams (s.d. 1747.71). Twenty seven percent (27%) of the respondents produced more than 1500 grams of gold per year. See TABLE 1.

**TABLE 1 : Annual production of gold of the small scale miners in Benguet**

| Amount (grams) | Frequency | Percentage |
|---|---|---|
| <150 | 5 | 15.15 |
| 150-300 | 4 | 12.12 |
| 301-450 | 4 | 12.12 |
| 451-600 | 3 | 9.09 |
| 601-750 | 1 | 3.03 |
| 751-900 | 1 | 3.03 |
| 901-1050 | 1 | 3.03 |
| 1051-1200 | 5 | 15.15 |
| 1201-1350 | 0 | 0 |
| 1351-1500 | 0 | 0 |
| >1500 | 9 | 27.27 |

## Cyanide exposure

Twelve percent (12%) of the respondent-miners were doing cocktailing of cyanide + limestone; cyanide + water + acetic acid + hydrochloride acid; and cyanide + copper. Their reasons for doing such were to remove the dirt or soil particles, to control the acidity of the soil mixture, and to be able to identify gold particles from soil particles. Cyanide has been used for about 6.0 years on an average of 38.5kg per application (TABLE 3).

Most of the respondent-miners were not using proper protective equipment as shown in TABLE 2. About 94% were not using coveralls, 76% of goggles, 48% of gas mask, 92% of apron, and 50% of gloves. However, 74% of the respondents were using head cover and 98% were using boots.

The most common health symptoms of the respondent-miners were hypertension (62%), followed by hypertensive cardiovascular disease due to left wall ischemia (14%) (TABLE 4). TABLE 5 shows the health injuries of the respondent-miners due to accidents such as secondary blasting, and stone crushing.

## Small scale mining and safety risks

The process of small-scale mining in Benguet is

**TABLE 2 : Distribution of miners by cyanide and dynamite usage**

| Factors | Cyanide | Dynamite |
|---|---|---|
| Duration of Use (years) | Average: 5.96 (s.d. 8.28) | Average: 9.5 (8.35) |
| Amount Used per Application (kilograms) | Average: 38.50 (s.d. 26.14) | Average: 10.625 (s.d. 12.92) |

**TABLE 3 : Distribution of miners by frequency of using personal protective equipment**

| PPEs | Frequency of Using PPE | | | |
|---|---|---|---|---|
| | 100% of the time | 50% of the time | Very rarely | Not at all |
| | Percentage | Percentage | Percentage | Percentage |
| Coveralls | 3.80 | 1.27 | 1.27 | 93.67 |
| Goggles | 11.25 | 7.5 | 5.0 | 76.25 |
| Head cover | 74.39 | 18.29 | 2.44 | 4.88 |
| Gas mask | 24.69 | 14.81 | 12.35 | 48.15 |
| Apron | 3.80 | 2.53 | 1.27 | 92.40 |
| Gloves | 21.25 | 15 | 13.75 | 50 |
| Boots | 97.56 | 0 | 0 | 2.44 |

**TABLE 4 : Distribution of health diseases among miners**

| Health Diseases/Illnesses of the Miners | Percentage |
|---|---|
| Hypertension | 62 |
| Hypertensive cardiovascular disease due to left wall ischemia | 14 |
| Headache | 5 |
| Dermatitis | 4 |
| Peripheral neuropathy secondary DM | 4 |
| Sinus bradycardia | 4 |
| Sinus tachycardia | 4 |
| Coronary artery disease due to old septal wal infarction | 4 |

***multiresponse**

**TABLE 5 : Distribution of health injuries among miners**

| Health Injuries of the Respondents |
|---|
| 1. 4th digit of right hand distal IP crushed by stone |
| 2. Deformity of 5th oligato secondary mine reactive injury |
| 3. Perforated left ear drum due to secondary blasting |

called dog hole mining. The first step in this technique is tunneling which is creating a pathway into the rock through digging. This process takes a few months or even years. Miners will first observe the quality and contours of the land to determine the location of gold from where they will conduct tunneling. Dynamite is used to blast out the rock and manual hand held tools such as mallets, chisels, and shovels are used for further digging. Gold ores are carried out of the tunnels using cart on wheels. Miners also carry an approximately 50 kilograms of ore on their shoulders to the ball mill site. Large ore fragments are crushed into small fragments using mallet and hand-held tool shaped like a big magnifying glass, with a wooden handle and a rubber loop attached for holding the ore together while it is crushed. The next step is ball milling/gravity concentration. Ball milling takes 5-6 days to crush 200 sacks of ore. A ball mill is a rotating metal cylinder filled with steel rods where the crushed ore is fed into with added water. This process further grinds the ore against the steel rods to produce sand-like ore. This sand-like ore is passed through a series of wooden or cement chutes lined with jute sacks. As water washes the sandy ore down the chutes, the heavier gold particles will stick to the sacks. The collected gold particles are then washed off the jute sacks and collected in a big tub and placed in a round metal pan. The gold particles are recovered through a constant circular motion until the gold particles are concentrated in the center of the metal pan. The gold particles that do not stick to the jute sacks or the mine tailings are collected in a pit at the end of the series of chutes. These are collected into sacks, placed in clumps on the ground, and sun dried. Sun-drying of ore takes 1-2 weeks. When dried completely, the tailings are mixed with lime (calcium carbonate) using a shovel and then passed through a mixing machine. Mixing of dried ore and lime to fill the cyanide pond takes 2 days. The third step is cyanide leaching and precipitation that usually takes up to 5-7 days. Ten (10) kilograms of cyanide is mixed with 1 drum of water. Forty (40) kilograms of cyanide is dissolved for mixing 200 sacks of tailings. The cyanide used by the miners is a solid in form, placed in a sack, immersed in a pit of water, stored in a metal drum, and dissolved in a pot of water. The cyanide solution is siphoned into the cyanide pond and left to react for 5-6 days. As it evaporates, more cyanide is added. After 5-6 days, the solution is siphoned through a drum containing a precipitate bag with 2 kilograms of zinc dust. This is done three times until the zinc-gold sticks to the lining The precipitate bag is washed thoroughly with water. The collected solid precipitate is dried by heating over a fire. The dried precipitate is placed in a clay pot and mixed with borax (sodium borate). The borax-precipitate is then heated under high temperature until it becomes molten. The molten mixture is cooled in a basin of water and re-heated in the clay pot. The molten mixture is poured into another bucket of water that is stirred continuously forming a black conglomeration of impurities. These impurities are discarded and the silvery particles left behind are again heated up. Nitric acid is added, which emits orange vapor. Borax is again added into the residue and re heated to further remove the impurities and until a gold nugget is obtained.

TABLE 6 shows the safety investigation of the 40 small scale industries. Safety tools such as ramps, scaffoldings, and stairs were not provided or were unstable. Other unsafe conditions were also identified- risk of fall during erection and dismantling of scaffolds, guard rails were not provided in scaffoldings, and there was overloading of scaffolds. Steel

**TABLE 6 : Safety measures investigation in the 40 small scale industries**

| Major Activity/ Dimension | Specific Requirements | Percent Violation |
|---|---|---|
| Ladder work | Ramps, scaffoldings, and stairs are not provided. | 100% |
| | Ramps, scaffoldings, and stairs are not secure and stable. | 100% |
| Scaffolds | Unstable Scaffolds (scaffolds consist of assembled frameworks of timber on which working platforms may be placed). | 100% |
| | There is risk of falls in the scaffolds. | 100% |
| | Guard rails are not provided in the scaffolding. | 100% |
| Steel erection | Safety nets are not placed below the various working levels, when the steel erection is done at higher heights. | 100% |
| Roof works | There is no proper anchorage for ladders and scaffolds | 100% |
| | Demanded earth moving task. | 100% |
| Tunnel Construction | Muscle strain from excavation, digging, and loading. | 100% |
| | Embankments and erection of screens are not done. | 100% |
| | Danger or risk of caving in of tunnel. | 100% |
| | Overhead framework of tunnel is not supported by steelworks. | 100% |
| | Overhead framework of tunnel is supported by woods only | 100% |
| | Extraction of underground ore takes hours. | 100% |
| Ore extraction | Extraction of ore is done manually and poses musculoskeletal strain. | 100% |
| | Extraction of ore involves use of explosives. | 100% |
| | Noise hazard when explosives are used. | 100% |
| | Cold exposure in underground mining. | 100% |
| | Risk of hearing impairment from explosives. | 100% |
| | Poor visibility in looking for ores to take out to surface | 100% |
| | Complete personal protective equipment not worn | 100% |
| | Personal protective equipment not appropriate. | 100% |
| | Fumes from cyanide present. | 100% |
| Panning and Extraction of gold | Handling of chemicals is unsafe. | 100% |
| | There is no proper ventilation for chemical exposures. | 100% |
| | There is no proper waste disposal. | 100% |
| | Disposal of wastewater into rivers and streams. | 100% |
| Labour Issues | Children are involved in small scale mining. | 100% |
| | Small scale mining is done near homes. | 100% |

erections were not supervised during installation. There was no proper anchorage for ladders and scaffolds. Roofs installed were fragile and could be blown during high winds or heavy rains. Tunnel construction caused muscle strain to the workers Embankments and erection of screens were not done. Overhead frameworks of tunnel were not supported by steelworks, but mere with wood. Workers manually extracted the underground ores which could last for hours. The task also involved used of explosives. Explosives created noise hazards. During underground mining, workers were exposed to cold environment and poor visibility in looking for ores to take out to surface. Workers were exposed to dust from manually extracting ores and noise from dismantling tunnel. Complete personal protective equipment (i.e., hard hats, safety shoes, gas mask, and shields) were not worn by the workers. During panning and extraction of gold, fumes from cyanide and mercury were present. Chemicals were handled unsafely. There was no proper ventilation for chemical exposures. There was no proper waste disposal such that wastes were drained into soil or ground and/or rivers and streams. Children were involved in mining. Mining activities were also done near the homes.

## DISCUSSION

### Safety issues in small scale mining

In this study, it was shown that working conditions of Benguet miners are physically demanding and dangerous due to heavy load, unstable underground structures, use of heavy tools and equipment, and exposure to toxic dusts and chemicals. These poor physical conditions in mining exacerbate the potential for injury or illness[14]. Particularly, digging and rock breaking activities pose greater risk of injury or fatality due to pit wall failures or tunnel collapses. In Indonesia, shaft or pit collapses frequently occurred between 2 to 5 times per year in small scale mining areas[26]. Manually crushing quartz-rich stone aggregate exposes workers to fine, crystalline silica dust which can eventually result to silicosis. In addition, life expectancy in mining areas in Bolivian Altiplano is barely 48 years due to widespread silicosis[27]. In China, methane or coal dust explosions were associated with at least 6000 deaths of miners annually[16]. Chemical dangers such as cyanide and mercury misuse, poor ventilation, electrocution and explosives misuse were also causes of mining accidents.

In this study, mining activities were done near homes. Mining communities near residential areas expose the whole community to environmental health hazards. In the study of Tesha[33], communities living in close proximity to mining areas were exposed to chronic noise levels resulting to hearing impairment. In another study in the Philippines, gold decomposition takes place inside the houses of the workers using the kitchen, and the study showed high levels of hair mercury and health problems among the miners such as kidney pain, respiratory problems, and dizziness stove[23]. Exposure to acute levels can result to kidney and urinary tract dysfunction, vomiting and potentially death[30].

ILO stipulates that child labor in mining is one of the worst forms of child labor. Children are far more vulnerable to chemicals, dust, physical strain[37]. In Ghana, children who were exposed to crystalline silica dust due from manually crushing quartz-rich stones were documented to develop silicosis. In this study in Benguet, Philippines, children were involved in mining activities, thus, exposing them to such mining hazards.

This study in Benguet, Philippines also shows that most of the respondent-miners were not using proper protective equipment such as coveralls, goggles, gas mask, apron, and gloves. The most commonly used PPEs were boots and head cover. ILO reports that occupational health and safety in ASM is in a dismal state because unsupported tunnels are observed in smallest underground mines, and improper protective equipment worn by the workers such as shorts and shirts; helmets, earplugs, masks, and gloves are occasionally or rarely worn[16]. Safety measures in small scale mining are often overlooked. Furthermore, the necessary resources needed in order to promote safety actions are inadequate or lacking[16] Buxton, 2013). This is problematic since the degree of contracting occupational health hazards and problems increases with less knowledge and negative attitudes towards occupational health safety[5].

### Occupational and environmental health risks in the mining sector

Gold mining has an impact on environmental and human health[4]. The use of cyanide and mercury during the process of extraction of gold poses serious health and environmental issues[22]. Leung[19] noted that similar hazards were observed in Lucub, Abra as well as in Kias gold mines of Benguet. Literatures have shown that the major factors of vulnerability of workers to occupational health hazards and accidents in mining activities are (1) insufficient knowledge on the use of machines and chemicals and (2) the improper use of personal protective equipments[3]. Similar findings are documented in other parts of the world. For instance, mining communities in Ghana have higher prevalence of contracting infectious and chronic diseases such as malaria as water pits serve as reservoir for mosquito to breed, and skin diseases due to the cyanide and mercury residues that go to water bodies which people use for basic necessities. Studies of Akabzaa and Darimani[2] showed health impacts due to gold mining community such as the increase prevalence of morbidity and mortality in the community. Studies have also shown that long term exposure to cyanide may result to decreased function of the thyroid gland and nervous system[18].

In this study, health injuries of the respondents were caused by accidents such as secondary blasting, and stone crushing. However, ILO[16] states that due to the illegal nature of small scale mining, accidents are underreported. Non-fatal accidents in artisanal small scale mining is about six to seven times greater than formal, large-scale operations.

## Cyanide-related diseases

Cyanide is an asphyxiant chemical and can be fatal to humans at concentrations around 250ppm in air. Exposure to cyanide can manifest in neuropathological lesions and optical degeneration[25]. In this study in the Philippines, peripheral neuropathy secondary to dermatitis was noted as one of the illnesses of the respondent-miners. Hypertension was also common among the respondent-miners in this study. This is similar to the results of the study of Hunter et. al.[12] in Mashonaland, Zimbabwe where women's level of blood pressure in mining areas was notably higher than those in large-scale agriculture and traditional economic activities.

The other illnesses reported by the respondent-miners were tachycardia, hypertension, headache, dyspnea, and bradycardia. These diseases of the respondents are considered as manifestations of chronic cyanide poisoning[28].

## CONCLUSION

Small scale mining poses harm and risk to both miners and the public when unprotected and unregulated. This study showed that there were safety and occupational hazards in small scale mining in Benguet, Philippines which is one of the largest mining areas in the country. The common health symptoms and problems among miners were hypertension, hypertensive cardiovascular disease due to left wall ischemia, and headache. Health injuries were documented due to secondary blasting, and stone crushing. Unsafe conditions were also identified. It is recommended that a comprehensive precaution which includes engineering and administrative controls as well as health promotion activities should be undertaken in order to minimize or prevent the risk of hazards in small scale mining. These programs should aim to increase awareness of the miners on best mining practices, and to promote education, training, demonstration, and monitoring in order to promote occupational and environmental safety and health in artisanal and small scale mining.

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