Assessment of occupational safety and health hazards exposure of workers in small-scale gold mining in the Philippines

by

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Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
AFRIM	Alternate Forum for Research in Mindanao
AL	Action Limit
AO	Administrative Order
ASM	Artisanal and Small-Scale Mining
BOSH	Basic Occupational Safety and Health
BSP	Bangko Sentral ng Pilipinas
CAR	Cordillera Administrative Region
CO	Carbon Monoxide
CSHC	Central Safety and Health Committee
DENR	Department of Environment and Natural Resources
DOLE	Department of Labor and Employment
DOJ	Department of Justice
ECC	Environmental Compliance Certificate
EMPAS	Environmental Management and Protected Area Sector
EO	Executive Order
GFMS	Gold Fields Mineral Services
GPP	Gold-Processing Plant
IEE	initial Environmental Examination
ILO	International Labour Organization
IP	Indigenous Peoples
KII	Key Informant Interview
LGU	Local Government Unit
LSM	Large-Scale Mining
MGB	Mines and Geosciences Bureau
NIOSH	National Institute for Occupational Safety and Health
OSH	Occupational Safety and Health
OSHC	Occupational Safety and Health Centre
OSHS	Occupational Safety and Health Standard
P/CRMB	Provincial/City Mining Regulatory Board
PCL	Priority Chemical List
PD	Presidential Decree
PNEL	Permissible Noise Exposure Limit
PPE	Personal Protective Equipment
RA	Republic Act
REL	Recommended Exposure Limit
SSGM	Small-Scale Gold Mining
SSM	Small-Scale Mining
SSMA	Small-Scale Mining Associations
TLV	Threshold Limit Values

UM	Underground Miner
UNEP	United Nations Environment Programme
WBGT	Wet-Bulb Globe Temperature
WEM	Work Environment Measurement
WHO	World Health Organization
VOC	Volatile Organic Compounds

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EXECUTIVE SUMMARY

This study examined the practices in the small-scale gold mining (SSGM) industry in the Philippines, particularly the working conditions of miners and workers during gold extraction and processing. It evaluated the miners' and workers' exposure to various occupational safety and health (OSH) hazards and recommended appropriate control measures for their maximum protection.

Although this research has built on the past studies regarding SSGM in the country, this is the first paper that measured the different health hazards in gold extraction and processing in the Philippines. The results of this study can provide policy-makers with the basis for strengthening, improving or developing new policies suited to the OSH conditions of underground miners (UMs) and gold-processing plant (GPP) workers.

Both qualitative and quantitative methods were used in this research. In particular, workers were interviewed using structured questionnaires to get their perceptions of the OSH hazards in their working conditions, processes and practices. Direct observations were also used to gain insights. Moreover, quantitative data were gathered through actual measurements, using industrial hygiene equipment of the physical and chemical hazards present in the workplace. Accordingly, the workers' exposure levels to the different health hazards were quantified.

However, this study is limited by the number of fully operating SSGM (UMs and GPPs) due to "illegal" or "no-permit closure" issues, weather conditions at the location, and the threat to the safety and security of the research team. Likewise, the respondents were hesitant to answer inquiries regarding workers' age and chemical utilization as the miners were aware on Child Labour Law (Republic Act (RA) No. 9231) and the ban on the use of mercury, respectively. Inasmuch as the research team wanted to measure comprehensively the OSH parameters set in this study, the wet condition underground could cause the measuring equipment to breakdown, thereby preventing the researchers from conducting actual measurements. Moreover, assessing the potential health effects among the workers is not covered in the study.

The results show that various health hazards (such as noise, dust, chemicals, inadequate ventilation, and so on) are present at the GPPs and UMs. However, a majority of the workers perceive these hazards to be not detrimental to their health. Incorrect work practices; improper handling, usage, storage and disposal of chemicals; and absence of adequate personal protective equipment (PPE) were also found at the sites, which all show that workers are more exposed to hazards.

The workers in all of the 16 GPPs considered in this study are exposed to high levels of silica dust during ore feeding and ball/rod mill operations. They are also exposed to hydrogen cyanide, nitric acid and carbon monoxide at concentrations detrimental to their health. Majority of the noise levels from different sources, processes done inside the ball/rod mills and enclosed refining areas, and during agitation/mixing/leaching have already reached or exceeded the action level of 85 decibels (dBA) and permissible noise exposure limit (PNEL) of 90 dBA.

The data gathered from the 14 UMs were limited due to the inaccessible location of the sites. What is notable, however, was the air velocities in the mines that should have provided thermal comfort to workers and should have diluted the contaminants underground. Despite having mechanical ventilation systems in some of the UMs, air velocities decrease as the measurement goes farther or deeper from the tunnel opening. Other OSH hazards such as biological, ergonomics and psychosocial hazards were also identified in both the GPPs and UMs.

This research has determined that there are gaps with the way SSGM companies, particularly the informal ones, provide for the needs of their workers. By juxtaposing the workers' exposure, workplace conditions and work practices vis-a-vis the current SSGM OSH-related laws and policies, the study could attest that the safety and health of SSGM workers in the Philippines are largely overlooked. Moreover, the overlapping and conflicting OSH-related policies prescribed by the concerned national and local governments lead to different rule interpretation and implementation.

1. INTRODUCTION

1.1 Background

The Philippines is a mineral-rich country. The Mines and Geosciences Bureau (MGB) of the Department of Natural Resources (DENR) cite that from the 30 million hectares (ha) of total land area of the Philippines, about 9 million hectares have high mineral potential. Mineral exports of the Philippines reached about 2.8 billion United States dollars (US$) in 2015, with gold and nickel as the country's top mineral exports. The estimated value of metallic minerals in the same year was 110.21 Philippine Peso (Php); about Php35.33 billion came from gold production, Php54.9 billion from nickel and nickel products and Php18.98 billion from copper production (MGB, 2017). Moreover, about 236,000 workers are currently employed in the country's mining industry.[1]

[1]This number includes the formal mining industry only as it is difficult to establish number of workers in the informal mining sector.

In 2017, the Gold Fields Mineral Services (GFMS) Gold Survey also ranked the Philippines 22nd in its list of the worlds' largest gold-producing countries (Thomson Reuters, 2018). As the fifth among the six Asian countries that produce 91 per cent of this precious metal in the continent, mining is undeniably a lucrative business in the Philippines. It has created significant economic activity in the country by providing livelihoods to communities and by serving as a vital part of the local people's daily activities. This particularly occurs in the mineralized areas, where large-scale mining (LSM) and small-scale mining (SSM) employment exist.

Lu (2012) defines artisanal small-scale mining as a single-unit mining operation with an annual production of unprocessed material of 50,000 tons or less. It is usually characterized as informal, illegal and unregulated by the government, and as an industry that uses little and/or obsolete technology, inadequate or lack of safety measures or health care, use of child labour, absence of protection for the environment and seasonal operation. It primarily depends on the financial needs of the miners and the price of commodity (Fraser Institute, 2012).

Small-scale miners, particularly those "doing the dirty works" (Verbrugge, et al., 2014), are still out of the mainstream society. They are often composed of individuals, groups, families or cooperatives that belong to the informal sector of the market, and are composed of the poor people or small groups who are without capital and largely depend on mining for sustenance (Lu, 2012). About 75 per cent of those employed in SSM are in subsistence mining, 15 per cent are small individual or family businesses, while the remaining 10 per cent are established commercial mining firms (Bugnosen, 2001). Individual or family mining businesses are more engaged in extracting aggregates and industrial minerals such feldspar, silica and limestone. On the other hand, most subsistence miners are in gold mining and sand and gravel extraction.

1.2 Policy environment

Two specific legislative codes govern SSM in the Philippines, namely: Presidential Decree (PD) No. 1899 and RA No. 7076. Both laws recognize that promoting SSM can generate employment opportunities (Artajo, 2012).

PD No. 1899: Establishing Small-Scale Mining as a New Dimension in Mineral Resources Development. This decree was issued in 1984 by then President Ferdinand Marcos to become the initial legislation that legalized SSM. It provides a licensing system, which includes provision for issuing SSM permits within existing mining claims subject to the consent of the claim holders (Bugnosen, 2001). It also aims to alleviate the living conditions in the rural areas and contribute additional foreign exchange earnings (Rey and Saturay, 2005).

Artujo (2012) listed the salient features of PD No. 1899 as follows:

a. SSM is defined as the operation of a single-unit mining operation that relies heavily on manual operation and has an annual production of less than 50,000 metric tons (t) of run-of-mine ore. SSM has the following requisites:
    - The work is artisanal, whether open cast or shallow underground mining, and do not use sophisticated mining equipment;
    - SSM operations have total capital not exceeding Php10 million during the effectivity of the permit and its renewal.

b. The Director of the MGB regional office may grant operators with SSM permits to cover a maximum area of 5 hectares as soon as the applicant fulfills the requirements.

c. All gold produced by small-scale miners will be sold to dealers authorized and licensed by the *Bangko Sentral ng Pilipinas* (BSP) (Central Bank of the Philippines).

RA No. 7076: People's Small-Scale Mining Act of 1991. This legislation aims to generate more employment opportunities in the mining sector and to provide an equitable sharing of the nation's wealth and natural resources by implementing the People's Small-Scale Mining Programme. Its salient features are as follows (Artujo, 2012):

a. SSM refers to those activities that rely on manual labour using simple implements and methods and do not use explosives or heavy mining equipment.

b. The permitting/licensing/registration system process is as follows:
    - A small-scale miner or processor needs to obtain a license, which is issued in an ID form. The license approved by Secretary DENR or his duly authorized representative shall be valid for two years and renewable every two years.
    - The Provincial/City Mining Regulatory Boards (P/CMRB) serves as the permitting and regulatory arm of small mining activities.
    - All persons engaging in SSM activities need to register with the P/CMRB as small-scale miners. To be registered, the applicant has to submit a copy of his/her small-scale miner's license and *barangay* certificate of six months residency.

- The P/CMRB will identify and designate certain lands as "People's Small-Scale Mining Areas" or *Minahang Bayan,*[2] to be approved by the DENR Secretary.
- Registered small-scale miners may organize themselves into cooperatives such that they can qualify for the awarding of a People's Small-Scale Mining Contract. The Board will evaluate, negotiate and award the contract, which will then be reviewed by the Secretary.

c. All gold produced by the small-scale miners will be sold to the BSP or its duly authorized representatives.

d. A total of 15 per cent of the government revenue share will be allocated to establish the People's Small-Scale Mining Protection Fund.

The provisions of PD No. 1899 and RA No. 7076 are overlapping and sometimes contradictory, which cause confusion and makes monitoring and regulating SSM activities difficult for the implementing agency (Artajo, 2012). Thus, in 2011, the Department of Justice (DOJ) issued Opinion No. 29 to clear the problem. Accordingly, the DOJ stated that RA No. 7076 completely repealed PD No. 1899.

Although RA No. 7076 was able to encourage small-scale miners to form cooperatives, it did not successfully uplift the small-scale miners standard of living. For one, the registration procedures for operating mining activities are highly complex as similar requirements are imposed on both LSM and SSM companies. For another, small-scale miners find the task of completing the requirements and processes of the law to be very tedious. Baluda (2002, p. 14) cited that,

> "An application for a small-scale mining permit requires that the small-scale operator secure an ECC[3] from the office of the Environment Management and Protected Area Sector (EMPAS), part of the DENR. But to obtain environmental compliance certificate (ECC), an initial environmental examination (IEE) has to be submitted to the regional office of the DENR in the Cordillera Administrative Region (CAR). This document is too technical

[2]*Minahang Bayan* areas (People's Small-Scale Mining Areas) are sites designated by the P/CMRB for small-scale mining (Verbrugge, et al., 2014). The *Minahang Bayan* was such that the government can regulate SSM in the country, and accordingly curb illegal mining and mitigate the adverse environmental impacts of indiscriminate mining operations in the Philippines. Specifically, by setting up *Minahang Bayan* areas*,* the government can centralize the processing of minerals within a zone in order to improve the monitoring of small-scale miners' gold production.

[3]An Environmental Compliance Certificate (ECC) is a certificate issued by the Environmental Management Bureau (EMB) of the DENR, which indicates that a proposed project will not cause significant damage to the Philippine environment. The ECC contains specific conditions that the project proponent must comply with before and during the project implementation. An ECC is granted to the applicant to certify that the proponent has submitted all the requirements of an environmental impact assessment and has committed to follow its environmental management plan (Triple-i Consulting, 2019).

for the small-scale miner to complete. And while licensed environmentalists can be called on to prepare the IEE, the cost (Php5000-20,000) is prohibitive."

In addition to these barriers, Verbrugge (2015) cited that various political barriers have made it challenging for artisanal small-scale mining (ASM) operators to be included in the formal economy. For one, the rent-seeking practices of government officials in the issuance of permits are pervasive; likewise, the system of allocating permits is plagued by patronage and nepotism. An operator needs to have high-level connections in the provincial government to increase his chances of being granted with a permit. As such, many SSM operators opt to engage in illegal mining activities.

In terms of ensuring the protection of workers in SSM, the government has issued several related Orders: DENR Administrative Order (AO) No. 30 series of 1997 and Executive Order (EO) No. 79, series of 2012.

<u>DENR AO No. 30, s. 1997 (DENR AO No. 97-30): Small-scale mine safety rules and regulations</u>. This Order aims to promote the welfare of the mining industry labourers. Specifically, the Order governs all contractors, associations, processors, permittees, operators, workers, individuals and other entities engaged in any form of SSM to implement safe and accident-free operations in SSM areas. The guidelines cover the health, sanitation, and safety rules and regulations. However, DENR AO No. 97-30 focuses more on preventing safety hazards; it has limited provisions on protecting workers against health hazards.

<u>EO No. 79, s. 2012 (EO No. 2012-79): Institutionalizing and implementing reforms in the Philippine mining sector providing policies and guidelines to ensure environmental protection and responsible mining in the utilization of mineral resources</u>. In 2012, the Aquino Administration issued this EO to institutionalize and implement reforms in the mining industry. In particular, the DENR is directed to amend the implementing rules and regulations of RA No. 7076. One salient provision of the Order is stated in Section 1, which initiates the exclusivity of the *Minahang Bayan* to small-scale miners, thus preventing large-scale miners from operating within the *Minahang Bayan* areas.

1.3 Socio-economic conditions

SSGM in the Philippines is usually done by individuals who surge to a mineral-rich area to extract the mineral after being attracted to the profitable character of gold production (Rey and Saturay, 2005). Mining is done in adjoining and commonly intersecting underground openings, which are owned and operated independently of one another (Rey and Saturay, 2005).

SSGM workers often group themselves under a corporation (*korporasyon*), a group of miners that work in a particular tunnel. The *korporasyon* is headed by a team leader, usually an experienced miner who commands the respect of the other miners. His main responsibilities include organizing the underground mining operations and monitoring the workforce, ensuring the unity of the *korporasyon*, and preventing the workers from leaving. The "runner", on the other hand, acts as the "eyes and ears" of the absentee financier (Verbrugge, 2015). There are also the *abanteros,* who mine the tunnels for ores that might contain gold, and the *antraseros* who are responsible for crushing the extracted ore and for transporting the sacks of crushed ore out of the tunnel to ball mill areas for processing. The members of the *korporasyon* are not limited to these: timberman, electrician and cook are also included in the *korporasyon.*

Usually, a *korporasyon* is financially backed by wealthy businessmen; they are the financiers who initially advance the operational expenses for the mining operations. Such operational expenses include the mining tools, sacks, generator, water pump and timber reinforcement. In some instances, the financiers also provide the workers with food and shelter; sometimes, the workers can also ask for cash advances (Verbrugge, 2015). Based on the size of the operations, the financiers also hire labourers to haul, pack and process the mineral. Sometimes electricians, chemists and engineers are also hired.

The number of labourers differs from one opening to another depending on the scale of the mining operations. The workers do not have fixed salaries or regular wages; instead, they are assured that that the financier would shoulder the expenses, food and allowance for labour; and that they would receive shares of the produce in the form of ores or their monetary value. The sharing may be based on gross production or gross income; usually, the operational expenses are already deducted beforehand (Tujan and Guzman, 2002). In some instances, some of the workers employed by the financiers do not receive any income at all for their labour until some gold is produced, which may take several months to a year (Rey and Saturay, 2005).

The proceeds of the excavation are divided between the workers and the financier based on an arrangement between the two parties. In Diwalwal, Tujan and Guzman (2002) cited that the sharing scheme is based on the ore produced or the total income derived from the operations. The usual sharing arrangement in the area is 30-70-30 per cent to the miners and 70 per cent to the financier. However, the labourers' share (that is, 30 per cent of the gross income) is still divided by the number of workers, which usually number in hundreds. This implies that the workers in SSGM and processing do not get much considering the risks they are exposed to and the amount of work they put in. It is for this reason that some miners and workers prefer smaller, self-financed operations due to the exploitative economic conditions in SSM backed by financiers (Verbrugge, 2015).

1.4 Working conditions

Generally, the work involved in SSGM and processing is done crudely and unsystematically; it is also hazardous and labour-intensive (Lu, 2012; Rey and Saturay, 2005). Moreover, miners work under dismal working and living conditions. They work long hours inside narrow and extremely hot tunnels, and they are constantly at risk from tunnel collapse due to the unsafe underground mine support beams and to the explosives used during extraction.

The workers also lack basic knowledge of mining, use crude techniques and equipment, and do not have the financial capacity to acquire the proper protective gears — all of which make the work involved in SSGM and processing harder and riskier. For one, the workers are at high risk of pulmonary diseases and even suffocation due to poor ventilation inside the mines (Vergrugge, 2015). For another, gold processors use mercury and cyanide in ore processing, which are supposedly restricted per DENR AO No. 1997-38, Chemical Control Order for Mercury Compounds and DENR AO No. 1997-39, Chemical Control Order for Cyanide and Cyanide Compounds; however, they are freely handled by SSGM workers with little regard for basic safety equipment. It is notable that during the course of data gathering, no children were engaged in mining activities. However, some studies have shown that children also participate in the processing of ores and are accordingly exposed to these health hazards (Baluda, 2002). All of these factors expose the workers to serious diseases and accidents.

The living conditions outside the tunnels are likewise hard. Most mines are located in remote areas; thus, the miners opt to work within the area away from their families. Likewise, the foodstuffs are basic, whereas the lodgings in the bunkhouse are merely composed of plastic sheet for cover and ropes as rudimentary beds (Verbrugge, 2015).

Torres, et al. (2002) have cited that the occupational health in SSGM operations is difficult to regulate due to the limited number of capable personnel who can plan, implement, monitor, and regulate health programmes. Moreover, despite the government’s efforts to formalize this industry, the status quo remains due to the prevailing socio-economic conditions of the communities where the industry operates. SSGM is considered as a fall back or a safety net that functions together with the formal employment offered by LSM companies. Moreover, the industry provides an assured source of income to the low-income families and to those unemployed. Accordingly, Rey and Saturay (2005) cited that such working conditions in SSGM may endure for as long as most of the small-scale miners are subsistence earners who can only make very few improvements or additions.

1.5 Rationale of the study

The Occupational Safety and Health Centre (OSHC) of the Philippine Department of Labor and Employment (DOLE) is one of the identified key agencies in the Philippines that would implement the United Nation's Minamata Convention on Mercury.[4] Accordingly, the agency recognizes that the government urgently needs to develop plans to reduce or to eliminate the use of the pollutant mercury from artisanal and small-scale mines to protect human health and the environment. However, despite the government's efforts to control the proliferation of illegal mining, it remains one of the largest users of hazardous chemicals, particularly mercury. One of the mechanisms established by the government to regulate and centralize mineral processing in an area is through establishing the *Minahang Bayan*.

However, issues on child labour, formalization, gold supply chains, poverty and discrimination among SSGM communities still prevail despite the government's efforts to address these problems in SSGM. The International Labour Organization (ILO) established the CARING Gold Mining Project[5] "to ensure that laws, policies and action plans to address child labour and to ensure that working conditions in SSGM are appropriate and strictly enforced" (ILO, 2019).

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[4]The Minamata Convention on Mercury is a multilateral environmental agreement that aims to address anthropogenic activities that contribute to widespread mercury pollution (EPA, 2019). The Convention further aims to protect human health and the environment from the harmful effects of mercury pollution by banning new mercury mines, phasing out existing ones, implementing control measures on air emissions, and enforcing international regulations on the informal sector for artisanal and small-scale gold mining (ASGM) (DENR, 2018). The Convention is named after an incident in Minamata Bay, Japan, in which a local chemical factory contaminated the whole area with methyl mercury. Consequently, thousands of people were affected; this was the first large-scale incident of methyl mercury poisoning.
The Philippines signed the Minamata Convention on 31 October 2015 and is currently being ratified for the Convention. To date, a ratification dossier has been prepared by the Environmental Management Bureau of the Department of Environment and Natural Resources. The dossier provides an overview of the current state of mercury pollution in the Philippines (including the existing laws and policies to control and regulate mercury pollution), the socio-economic and environmental impacts of the Convention, and the Philippines' national action plans and strategies to comply with the Convention. The final draft will be concurred by the following agencies responsible for fulfilling the Philippines' commitments to the Convention: Department of Trade and Industry (DTI), Department of Energy (DOE) and OHSC of the DOLE (DENR, 2018).

[5]The CARING GOLD MINING PROJECT (Convening Actors to Develop and Implement Strategies to Reduce Child Labour and Improve Working Conditions in Artisanal and Small-Scale Gold Mining) is a four-year project of the ILO funded by the United States Department of Labor. The project started on December 11, 2015 and ended on April 10, 2019, and aimed to address child labour and the poor working conditions in the ASGM sub-sector in the Philippines (ILO, 2019). Specifically, the project has established legal and regulated *Minahang Bayan* areas that comply with environmental, health and labour standards. The CARING Gold Mining Project had the following components (ILO, 2019): (a) strengthening of laws, policies and action plans and their enforcement and implementation to better address child labour and working conditions in SSGM; (b) facilitating the access of vulnerable households living in SSGM communities to social protection and livelihood programmes and supporting their transition to formal operations; (c) setting up and implementing mechanisms to increase transparency and to monitor child labour and working conditions in gold mining supply chains, particularly SSGM, by mandated Government agencies and mining related stakeholders; (d) setting up of global networks to reduce child labour and to improve working conditions in SSGM; and (e) supporting and disseminating innovative solutions to reduce child labour and working conditions in SSGM.

Various studies have been conducted under this project. This present study, in particular, focuses on assessing the exposure of workers to OSH hazards in SSGM by conducting actual measurements of health hazards with specific indicators. Accordingly, this study can serve as an empirical basis for strengthening existing policies and for developing new policies and guidelines that would improve and ensure quality OSH conditions of SSGM workers.

It is in this light that the OSHC, DOLE and the ILO have worked together to determine the extent of workers' exposure to various safety and health hazards and to identify the other essentials that the SSGM sub-sector needs. This current study focuses on the possible amendments to SSGM OSH rules and/or crafting of unified regulations to ensure workers protection.

1.6 Objectives

In support of the CARING Gold Mining Project of the ILO, this study aims to assess the OSH status of workers in selected SSGM areas in the Philippines. Specifically, this study aims to:

a. Describe the working conditions and practices of workers during the extraction and gold processing.

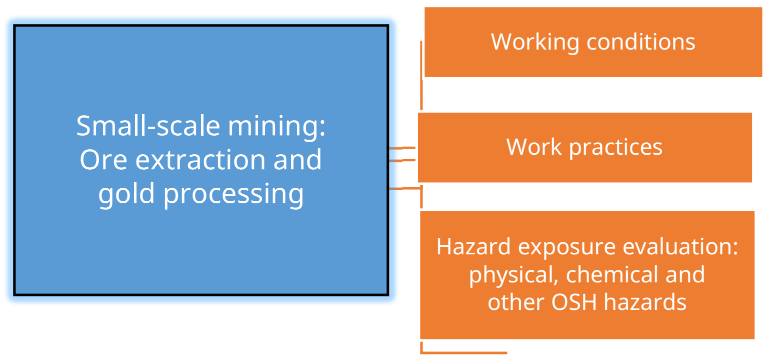
b. Evaluate the miners' exposure to physical, chemical and other OSH-related hazards during extraction and gold-processing activities.

c. Examine the implementation gaps in SSGM-related safety and health policies and standards for workers, particularly the gaps in the implementation of OSH-related policies.

d. Provide policy recommendations on the appropriate control measures that would minimize workers hazard exposure and enhance the protection of workers.

Figure 1 illustrates the framework used in this research. In particular, it presents the parameters measured in this study in order to evaluate the OSH hazards that workers in the UMs and GPPs are exposed to.

Figure 1. Framework for assessing OSH hazard exposure level of workers in selected SSGM sites



1.7 Significance of the study

The results of this study can help policy-makers in developing policies that cover the protection of workers. In particular, this research can provide the empirical basis for formulating appropriate recommendations that would ensure working conditions, update existing guidelines for safe work practices, and minimize workers' exposure to different OSH hazards. Moreover, this study could guide the government in improving the relevant standards and department orders/issuances pertaining to OSH rules and regulations in the SSM industry. It could also serve as a basis for developing specific health and safety programmes, for establishing workplace policy to ensure protection among the vulnerable small-scale miners, and for implementing preventive programmes on SSM occupational hazard exposures.

This research is also in line with the objectives of the Philippine Development Plan 2017–2020 and the *AmBisyon Natin 2040* (Our Vision for 2040)[6] as the national government's framework for development. In particular, this study will serve as a means to fulfill the two of the Eight-Point Labour and Employment Agenda of the present Duterte administration, namely: (a) to ensure full respect of labour standards; and (b) to bring more focus and accessibility in workers protection.

[6] *AmBisyon Natin* 2040 is the collective long-term vision and aspirations of the Filipino people for themselves and for the country in the next 25 years, as gathered from the result of a long-term visioning process that began in 2015 through focus group discussions (FGDs) and surveys. Specifically, more than 300 citizens participated in the FGDs and close to 10,000 answered the national survey. Accordingly, the government prepared technical studies to identify the strategic options in order to achieve the vision shared by the citizens. *Ambisyon Natin* 2040 is the picture of the future of the Filipino people—a set of life goals and goals for the country. It is different from a plan, which defines the strategies to achieve the goals. *AmBisyon Natin* 2040 is the vision that guides the future and is the anchor of the country's plans (NEDA, 2016).

2. REVIEW OF RELATED LITERATURE

The previous chapter has given an overview of the policy framework under which the SSGM industry in the Philippines operate. Such environments may have contributed to the dismal working conditions of SSGM workers in the country, in which the safety and health of the workers are largely overlooked. This chapter then discusses the related studies that have focused on the OSH that SSGM workers, both in other countries and in the Philippines, are exposed to in the process of gold extraction and processing.

2.1 SSGM operation and associated hazards

The practices and techniques used in gold extraction and processing require using hazardous materials and procedures that can endanger the safety and health of workers and the people in nearby communities when materials, tools, and the associated activities are not handled properly. SSGM affects approximately 15 million miners all over the world, thereby causing serious public health problem (Bose-O'Reilley et al., 2016). The World Health Organization (WHO), (2016) listed six main steps in SSGM, namely, *extraction*, *processing*, *concentration*, *amalgamation*, *burning* and *refining*.

Extraction involves removing the sediments and mining the ore from underground through surface excavation, tunnelling or dredging. Explosives are sometimes used in the initial excavation, which can expose workers to dangerous levels of dust, noise, vibration and asphyxiation (WHO, 2016). Moreover, improper use of explosives can also lead to death due to traumatic injury (Harari and Harari-Freire, 2013). Likewise, accidents can happen during the extraction process due to rock falls or cave-ins, especially when the mines have unstable pillars and substandard supports.

Meanwhile, *processing* includes separating the gold from the other minerals in the ore, and the method for doing this depends on the type of deposit. Gold particles in alluvial deposits do not require mechanical treatment. On the other hand, if the gold is in hard-rock deposits, miners have to crush and mill the deposits. The initial crushing can be done manually through hammers or other simple tools. Thereafter, miners have to grind the ore into smaller particles. In this process, crystalline silica dust is released into the air when miners drill, transport and crush ore to extract the gold from the ore (Gottesfeld, et al., 2015). Accordingly, if the workers do not wear the proper protective gears, then constant exposure to silica dust can cause silicosis[7] and lung cancer, chronic renal disease and autoimmune diseases such as rheumatoid arthritis (NIOSH, 2002).

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[7]Silicosis is a lung disease that happens when an individual frequently breathes in tiny bits of silica, a mineral that is part of sand, rock and mineral ores. This disease is commonly found in workers exposed to silica, such as miners and glass manufacturers. When an individual is constantly exposed to such environments, lung scarring may eventually develop, which may then cause breathing difficulties (American Lung Association, 2015).

In some instances, the gold has to be further separated from the other materials by *concentration.* This is done through various techniques such as sluices, centrifuges, vibrating tables, and so on. Since the density of gold in the ore is higher than the other minerals, most miners use gravity for *concentration* (WHO, 2016).

Amalgamation is the next step in the SSGM process. *Amalgamation* is a concentrating process in which the gold is mixed with mercury such that the gold bonds with mercury to form the gold-laden mercury amalgam (Mine Engineer, 2012). This process is highly dangerous to any individual as mercury is a well-known toxic substance that can cause very detrimental effects on one's health depending on the individual's susceptibility and exposure to the substance. Mercury is a well-known neurotoxin that can cause permanent brain damage to an individual (AGC, 2019). Symptoms of mercury poisoning include dizziness, difficulty in concentration, muscle twitching, poor muscle coordination, memory loss, blurred vision and numbness in the hands and feet. Acute health effects also include kidney failure following exposure to high concentrations of inorganic mercury (Cortes-Maramba, et al., 2004).

Cyanide is also used in extracting gold, albeit this chemical is often applied after mercury has already been used (World Health Organization (WHO, 2016)). Cyanide is considered one of the most cost-effective methods of extracting bits of gold from the rock deposit. It quickly degrades into other non-toxic substances, not necessarily a poison, and can be found anywhere in nature in its non-toxic state (Lu, 2015). However, when cyanide bonds with other chemicals, the resulting compound becomes very toxic and lethal to human health and to the environment. In fact, being exposed to even small quantities of hydrogen cyanide can be fatal to humans (Leung and Lu, 2016). Moreover, cyanide is easily absorbed from all routes of exposure entry.

The next step in the SSGM process is *burning*, in which the amalgam is heated to vaporize the mercury and separate the gold (WHO, 2016). In "open burning", the mercury vapour is emitted into the air. In this method, not only the workers become exposed to the vapours, but the communities near the mining sites as well. Mercury vapour when inhaled by individuals, can cause erosive bronchitis, interstitial pneumonitis and other lung-related diseases. Likewise, when mercury is released into the air, it can travel long distances before it is deposited into waterways and soils. Consequently, the bacteria in the soil and waterways will convert mercury into an even more toxic form called methylmercury, which can become concentrated inside the bodies of living things (that is, fish) when they are ingested, thereby becoming included in the food web (AGC, 2019).

The final step in the SSGM process is *refining.* This process is done when the "sponge" gold is further heated to remove the residual mercury and other impurities (WHO, 2016). Aside from mercury, workers are also exposed to other harmful chemicals, such as nitric acid and caustic, during the refining process. Accordingly, nitric acid can damage skin cells when it comes into contact with the skin.

Overall, the work required in SSGM is physically demanding and dangerous. Aside from the chemical hazards, SSGM workers are exposed to biomechanical, psychosocial and physical hazards such as over-exertion, physical trauma, noise, heat and humidity (WHO, 2016), due to the heavy workload and to the generally poor working environment.

2.2 SSGM workers' exposure to safety and health hazards

The WHO (2016) categorizes SSGM-related hazards as *chemical*, *biological*, *biomechanical*, *physical* and *psychosocial*. Exposure, on the other hand, is a process that causes contact with environmental hazards (such as, risk agents) that connects "hazards" to "risks" (Haq, et al., 2018). This section details some of the studies that measured the workers' exposure to the safety and health hazards and the effects of these safety and health hazards on the SSGM workers in other countries and in the Philippines.

2.3 Chemical hazards

The previous section has already established that miners are susceptible to inhaling, absorbing and ingesting chemicals due to the processes involved in extracting and processing gold. In particular, miners are exposed to the naturally occurring silica from the ore, they use mercury, cyanide and nitric acid to extract gold from the ore and to purify gold. Exposure to all of these chemicals has detrimental effects on the health of miners and the people residing in nearby areas.

In Indonesia, about 250,000 SSGM workers use mercury for amalgamation and then release it to the environment during the gold-refining process (Haq, et al., 2018). Haq, et al. (2018) analysed the mercury levels in the environment around SSGM operations in Lebaktu sub-district, Banten province and found that the levels of mercury at the research sites on rice, fish and vegetables had averages of 0.0.27 mg/kg, 0.283 mg/kg and 0.410 mg/kg, respectively. Based on the risk assessment conducted by the authors, the mercury content in the foodstuffs can potentially put the community who consumes these at risk. Likewise, in Bogor and Cikotok in West Java, Indonesia, Hidayati, et al. (2009) cited that rivers, ponds and paddy fields around small-scale gold mines had been mostly contaminated by mercury in considerably high levels — from 7.73 ppm to 22.68 ppm. Meanwhile, the rivers around large-scale gold mines were contaminated by cyanide at 0.15 ppm in its sediment.

In the Philippines, mercury and cyanide are subject to the Priority Chemical List (PCL) and Chemical Control Order of the DENR. The use of mercury is prohibited under DENR AO No. 97-38, whereas DENR AO 97-39 regulates the use of cyanide. Unfortunately, data are limited on the actual measurements of health hazards such that they can be used for the study recommendations.

Cortes-Maramba, et al. (2004) conducted an environmental monitoring by measuring the ambient air quality in a gold-mining community in Sibutad, Zamboanga del Norte. Their results showed that three sampling sites in the research area exceeded the standards for mercury in the ambient air. The blood and hair samples of the subjects residing within the research site also had elevated total mercury levels and elevated methylmercury levels. The United Nations Environment Programme (UNEP) also reported that five out of 100 residents from Mount Diwalwal, Compostella Valley had blood mercury levels of >75 µg/mL, whereas 39 residents had blood mercury levels of >15 µg/mL; the permissible limit is 15 µg/mL (UNEP, 2010). These results indicate the environmental and occupational exposure of residents to the SSGM operations in the area.

Meanwhile, Leung and Lu (2016) conducted a cross-sectional study to assess the cyanide exposure of SSGM workers in two mining sites in Benguet, Philippines. Their methods consisted of interviews, laboratory examination and blood cyanide determination. Their results showed that all of the 34 miners tested positive for cyanide in their blood samples. Five of the subjects had levels above 0.5 µg/mL, which is the level for acute toxicity among smokers. Likewise, cyanide was detected even in the blood of those miners who did not handle this chemical in their work. This indicates that they have been exposed to the chemical despite not being directly involved in cyanide-related mining activities. It was found out later on that many of them lie near or regularly pass by the cyanide leaching ponds. Leung and Lu (2016) also reported that the respondents experienced pulmonary edema and loss of consciousness, which are said to be manifestations of the later features or most severe cases of cyanide poisoning. Meanwhile, Lu (2015) conducted another study in a mining site in Benguet, Philippines and reported that the respondent miners were also experiencing tachycardia, hypertension, headache, laboured breathing and abnormally slow heart reaction. Such illnesses and symptoms are considered to be manifestations of chronic cyanide poisoning (Reade, et al., 2012).

Researchers have also found evidence that SSGM workers are exposed to crystalline silica dust, which puts them at risk to diseases such as silicosis, lung cancer and other lung-related diseases. Gottesfeld, et al. (2015) conducted an air sampling in the breathing zones of SSGM workers in five SSGM villages in Tanzania and measured the concentration of crystalline silica in the samples. The authors found out that airborne crystalline silica exposures of the workers and surrounding communities exceeded the recommended limits. In particular, the average exposure measured 16.85 mg/m^3 for underground drilling, which is 337 times greater than the recommended exposure limit (REL) prescribed by the US National Institute for Occupational Safety and Health (NIOSH). On the other hand, the exposure of the workers in aboveground operations measured 0.19 mg/m^3, which is four times greater than the REL. Similarly, Tse, et al. (2007) found that the prevalence of silicosis among the small-scale gold miners in Jiangxi, China was at 29.1 per cent after 5.6 years of dust exposure. They also determined that the concentration of respirable silica dust was at 89.5 mg/m^3 (ranging 70.2–108.8 mg/m^3) in the underground gold mine. These values far exceed the permissible exposure limits.

In the Philippines, Lu (2015) reported that 69.2 per cent of the miners in two mining sites in Benguet have been exposed to dust, whereas 30.6 per cent have been exposed to chemicals.

2.4 Biomechanical (ergonomics) and physical hazards

The WHO (2016) cites that biomechanical hazards due to heavy workloads, repetitive tasks, long working hours and unsafe equipment associated with SSGM can lead individuals to develop musculoskeletal disorders. Physical hazards, on the other hand, can include vibrations, loud noise and heat and humidity — all of which are present in SSGM.

Long, et al. (2015) examined incidences of accidents, injuries and potential risk factors in a Ghanaian SSGM community. They found out that out of the 173 participants of the survey, injury rates were at 45.5 per cent. The most common types of injuries were cuts or lacerations, burns and scalds, and contusions and abrasions. Likewise, Leung and Lu (2016) found that the most frequently cited accidents suffered by SSGM miners in Benguet, Philippines were trip and falls, being hit by machinery or a moving object, and effects of cave-ins or rock falls.

Meanwhile, Kusena and Zhou (2014) stated that most of the sources of heat in SSGM sites in Ward 19, Zvishavane, Zimbabwe were terrestrial heat from machinery like jackhammer and from workers themselves. They measured that terrestrial heat at the site tended to increase with depth at around 3°C per 100 m. Accordingly, such heat and humidity can cause health effects, such as dizziness, faintness, shortness of breath or breathing difficulties, palpitations and excessive thirst (Walle and Jennings, 2001 as cited by WHO, 2016).

Due to the nature of the work in the mines, some researchers have found out that a high proportion of the mining industry's workforce are exposed to vibration, particularly whole body vibration, which is generated from operating the tools and machinery (WHO, 2016; Kusena and Zhou, 2016; Schenid, 2009). A survey sponsored by

Safe Work Australia (2010) highlights that approximately 24 per cent of the overall workforce in the mining industry self-reported exposure to vibration. Just like in other workplace exposures, as the level of vibration transmission to the operator increases, the more it causes fatigue and higher risk of injury. According to Schenid (2009, as cited by Kusena and Zhou, 2014), the incidence of Raynaud's phenomenon[8] among Korean small-scale mine workers was 33 per cent.

The problem of noise is also prevalent in SSGM operations due to the type of machinery used in the processing of gold and the confined spaces where the miners work. Noise due to drilling, blasting, cutting, materials handling, ventilation, crushing, conveying, and ore processing are pervasive in mining. The US Centre for Disease Control (2018) cites that majority of miners are exposed to hazardous noise — the highest prevalence among all major industries. According to statistics, one out of every four mine workers have hearing problems; what is even worse is that hearing impairment of four out of five mine workers have been diagnosed when they reach mid-60s to retirement age (CDC, 2018).

The results of the interview conducted by Kusena and Zhou (2014) with the SSGM owner indicated that the noise level at the research site, based on the last time their last measurement, was above 120 dB. Accordingly, any sound above 85 dB is harmful to humans. Similarly, the communities living near the mining areas in Tanzania have been exposed to chronic levels of loud noise, which have resulted in hearing impairments (Tesha, 2003 as cited by Lu, 2015).

2.5 Biological hazards

Biological hazards refer to organisms or organic matter produced by these organisms that pose threats to human health (OSHC, 2003). Sources of biological hazards may include bacteria, viruses, birds and other animals, and humans. Due to the poor working environment in SSGM sites, SSGM communities are susceptible to a variety of infections, among which are water-borne and vector-borne diseases and communicable diseases such as tuberculosis (WHO, 2016).

Kusena and Zhou (2014), in their study regarding the occupational hazards, injuries, and illnesses of SSGM workers in Zvishavane, Zimbabwe, cited that 23 per cent of the respondents in the SSGM site contracted malaria. The respondents pointed out that the damp conditions in the mining site had exacerbated the conditions in the area as it had created conducive environment for mosquitoes. In Ghana, Akabzaa and Darimani (2001) reported the high prevalence of malaria in Wassa West District, a mining community in the Tarkwa mining region in the country. The annual incidence of

[8]Raynaud's phenomenon is a disease characterized by the spasmodic contraction of the blood vessels of the fingers, which causes the fingers to be temporarily white and numb. This disease is commonly attributed to conditions that cause whole body vibration (WHO, 2011).

the disease was estimated at 185/1000 against the national average of about 40/1000. Moreover, the authors noted that in 1994, 75 per cent of the miners were carrying the malaria parasite. Based on the interviews that the authors conducted with the respondents, they determined that the mining activities being done in the area contributed the most to this high prevalence of malaria. Miners create open pits and divert watercourses, which subsequently result in bodies of stagnant water.

Likewise, the poor sanitation and waste management in mining sites can cause water-borne diseases to proliferate. In the East Akim Municipality, Ghana, an outbreak of cholera was attributed to the unhygienic practices of small-scale gold miners (Opare, et al., 2012). The authors assessed the environment in the municipality and determined that most of the water bodies were macroscopically dirty due to the indiscriminate mining activities.

2.6 SSGM work practices and OSH hazards

Many of the safety and health problems in SSGM industry are exacerbated by the following factors (WHO, 2016; Leung and Lu, 2016):

a. Absence of regulation in the SSGM sub-sector.
b. Lack of miner education on the safety and health hazards in SSGM operations.
c. Miners' unsafe work practices and environment.
d. Limited access to protective equipment.
e. Low level of occupational safety and health care.
f. Lack of or limited use of mechanization.
g. Poor qualification of personnel at all levels of operation, and so on.

In the study of Kusera and Zhou (2014), the authors noted that the major occupational injuries in the three SSGM research sites they had studied in Zimbabwe were caused by substandard maintenance of tools and equipment, poor communication, poor housekeeping, at-risk behaviour, use of explosives, inadequate PPE and lack of training and experience. Survey results showed that most injuries and illnesses at the mining sites were caused by lack of PPE (23 per cent), poor housekeeping (19 per cent) and substandard maintenance of tools and equipment (19 per cent).

The same unsafe practices and hazardous environments were observed in the Philippines. Leung and Lu (2016) reported that the most prevalent hazard observed in Benguet SSGM sites was exposure to cyanide in which the workers usually handled with bare hands. At most, the workers used handkerchief or a piece of cloth as face masks during the process of cyanide leaching and during smelting. Murao, et al. (2002) even reported that SSGM workers conducted gold decomposition inside their own houses, specifically inside the kitchen. Likewise, Leung and Lu (2016) reported that none of the workers were using a respirator, which made them susceptible to dust inhalation. SSGM operations in South Cotobato, meanwhile, even conducted operations within residential areas; such as, hazardous chemical can leach into soil and contaminate the ambient air, thereby endangering the residents within the area (AFRIM, 2012).

The SSGM workers in the two mining sites studied by Leung and Lu (2016) in Benguet wore only bonnets and caps as their head protection; the recommended head gear should be hard hats. The miners used only short-sleeved or sleeveless shirts and shorts, which made them vulnerable to hazardous chemicals such as nitric acid.

In another study in the Philippines, Lu (2015) reported the same findings — most of the respondent-miners were not using PPE. About 94 per cent of the respondents were not using coveralls, 76 per cent had no goggles, 48 per cent had no gas mask, 92 per cent did not use apron and 50 per cent had no gloves. The OSHC-DOLE found the same results when the agency investigated the mining sites in Camarines Norte (DOLE, 2015). Specifically, the OSHC found safety issues including unsafe tunnels, insufficient ventilation and absence of PPE for workers.

Education and trainings on OSH among SSGM workers are likewise almost non-existent. Long, et al. (2015), in their study in the SSGM site in Ghana's Upper East Region, found out that only two miners out of the 173 miner-respondents had ever received any occupational safety training. Meanwhile, Kusena and Zhou (2014) determined in the three mining sites in Ward 19, Zvishavane, Zimbabwe that there was no adequate funding in safety and health issues in all the mines surveyed. The mine owners indicated that they were only making marginal profits to the extent that they could not spare some money to invest in safety issues.

Likewise, the OSHC-DOLE investigated the mining sites in the towns of Camarines Norte, Philippines in 2015 (DOLE, 2015) and found the following issues:

a. *Safety issues* which include unsafe tunnels, insufficient ventilation and absence of PPE for workers.

b. *Inadequate training needs* specifically on mine safety and health hazards awareness and mine safety training/orientation).

c. *Inefficient administrative and management of operations* on the development of OSH committee and programmes, qualification of safety and health personnel, company policy on supply and utilization of PPE, and so on .

The Alternate Forum for Research in Mindanao (2012), in their study of the SSGM sites in Benguet and South Cotobato found that the local provincial governments practice poor governance and weak policy enforcement. This is mainly because the

SSGM sub-sector in these provinces is considered a significant part of the social, cultural and economic practices in the study areas. Regulating the SSM sub-sector has become especially difficult in areas where SSM is already a way of life. For example, the AFRIM (2012) reported that SSM operations in Benguet are historically part of the indigenous peoples' (IPs) way of life — SSM defines their cultural identity. Imposing regulations becomes problematic when the regulations run against their deep-seated cultural practices.

Moreover, SSM operations contribute to local revenue generation and provide employment in the rural areas. Hilson (2002) cites that SSM plays a significant role in poverty alleviation in rural regions since it can operate in remote areas that have minimal infrastructure where no other industries can thrive otherwise. More importantly, the SSM industry provides livelihood to women and IPs — the marginalized sector. It is estimated that women could account for about a third of the work force in the SSM sector (Hilson, 2002). Labone (1996, p. 119) reported that women "work in almost all aspects of the SSM operation, especially in panning, carrying, washing and sorting of ores, and have done so for generations". This is especially true in Benguet and South Cotobato, where the women are hired to wash the ores and sacks and to participate in gold processing (AFRIM, 2012). For these reasons, the government may be ambivalent toward disrupting the status quo, thereby leading to weak policy enforcement.

3. METHODOLOGY AND LIMITATIONS

3.1 Methodology

This study used a combination of qualitative and quantitative scientific research design to determine the workers perception of the different OSH hazards in their workplaces. Qualitative data were gathered through key informant interviews (KIIs) with workers and with permittees or contractors from both small-scale UM and GPPs. Specifically, this study used structured questionnaire-guided interview tools designed for workers and permittees or contractors.

The research team also conducted a walk-through of the working areas to directly observe the working conditions, work processes and workers practices, and accordingly identify other OSH hazards that cannot be quantified or measured.

On the other hand, quantitative data were collected through actual measurements of the physical and chemical hazards. The researchers used industrial hygiene equipment to determine the level of workers' exposure to different health hazards. Different research teams were assigned per study site; thus, a standard work environment measurement data form and sampling techniques for the physical and chemical hazards were used to minimize biases and to make data analysis easier.

Physical hazards such as noise, heat and ventilation were measured using direct reading instruments, whereas chemical samples (such as, hydrogen cyanide, nitric acid and different gases) were collected using air sampling devices. Following the standard protocol of handling and storage, the collected air samples were transported and analysed in the OSHC laboratory.

Ore samples were collected from specific SSGM sites to monitor the workers dust exposure. Accordingly, the samples were analysed in an accredited laboratory to determine the silica content present at the SSGM sites monitored. This component is important in computing for the threshold limit values (TLV) such that the research team could properly evaluate the workers' exposure to silica dust.

The results of the workplace assessment and exposure monitoring were evaluated based on the OSH standard (OSHS) of DOLE. The researchers used the American Conference of Governmental Industrial Hygienists (ACGIH) if the data could not be evaluated using the local standards.

3.2 Study areas

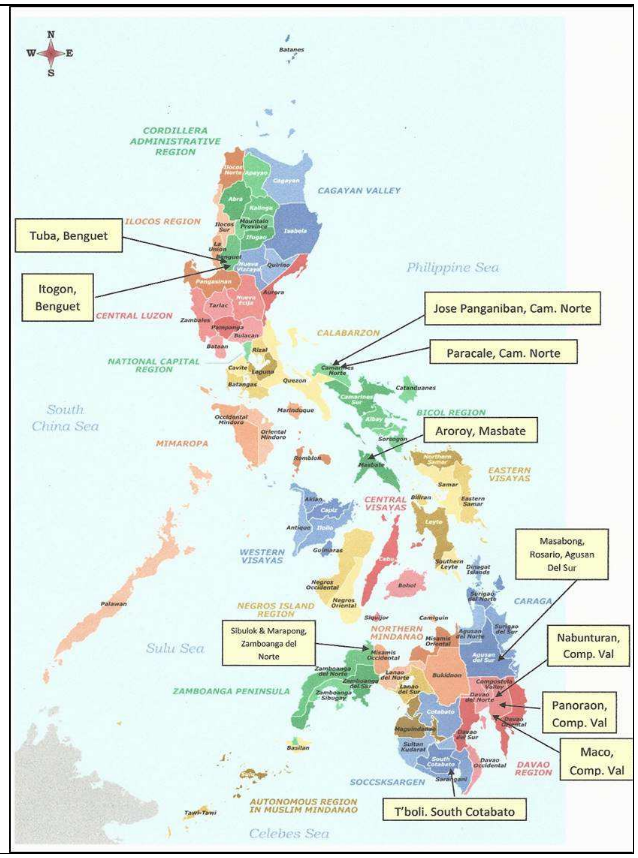
The target sites were the *Minahang Bayan* areas or the small-scale UMs listed in the *Minahang Bayan* petitioners' list. This list is handled by the MGB of the DENR. Two GPPs and two UMs from each region with mining areas were then selected. Site selection was based on the approval of the P/CMRB, local government units (LGUs) and small-scale mining associations (SSMAs); and of the permittees, operators, contractors or owners of the GPPs and UM sites.

Accordingly, 16 GPPs and 14 SSGM sites in Luzon and Mindanao agreed to participate in the research. The areas covered were Benguet, CAR, Camarines Norte and Masbate in Region V; Zamboanga del Norte in Region IX; Compostela Valley in Region XI; T'boli South Cotabato in Region XII; and Agusan del Sur in Region XIII. Moreover, two of the sites visited were the pilot areas for the ILO's CARING Gold Project (Figure 2).

Figure 2. Study areas

Study areas
CAR
Region V
Region IX
Region XI
Region XII
Region XIII

16 Gold processing plants/areas
14 Small-scale gold mine sites



3.3 Limitations

The analysis of this study is limited by the number of fully operating SSGM (UMs and GPPs) due to "illegal" or "no-permit closure" issues, weather conditions at the location, and safety and security of the research team. Most UMs are inaccessible primarily due to their locations and physical condition (uphill and actual condition underground), which prevented the team from conducting proper data collection in these areas. Likewise, the GPP study sites had varied operational conditions — some are fully operational whereas the others are not. Thus, the parameters measured in some of the study sites were different from the other sites. In other words, not all of the UMs and GPPs were measured for the same parameters.

Also, the operators were hesitant to answer the research team's inquiries regarding the workers' age and chemical utilization; the miners were aware of the provisions of the Child Labour Law (RA No. 9231) and of the ban on the use of mercury. Inasmuch as the research team wanted to present a comprehensive evaluation of the UM sites, the wet conditions underground prevented the researchers from conducting actual measurements at the sites; the measuring equipment may break down should accidents at the sites occur.

Lastly, this study did not assess the potential health effects of the identified safety and health hazards among the SSGM workers.

4. RESULTS AND DISCUSSION

4.1 Demographic profile

A total of 105 respondents participated in the study, namely, 50 underground miners and 55 GPP workers. The types of work done in the GPPs have more variety than those in the UMs. Given this, the job profiles of the GPP respondents were more varied and distributed than those of the UM respondents.

In this study, GPPs are referred to as those plants that have complete production processes (namely, ball milling, leaching/agitation, retort/ashing and refining) and those where only ball/rod and mill/s operate. Considering the setup and varied processes in gold production, work assignments are not limited to feeding, milling, panning, retorting, ashing and refining; they also include chemical mixing, welding, maintenance, and so on. Consultants, safety engineer and pollution control officer are hired for process monitoring and/or for other legal compliances.

Among the workers, more than 50 per cent (61 workers) are within the age range of 25-40 years old of which four are females. Although none of the respondents were below 17 years old, two workers were already in their senior years (older than 60 years old).

About 74 per cent (34 workers out of 50) and 58 per cent (32 out of 55) work for eight hours a day in the UMs and GPPs, respectively. The number of workdays per week is more varied in the GPPs than in the UMs because of the mine workers' different work arrangements. Majority of the miners (60 per cent) work six days a week. The workers opt to stay at the mine sites due to the distance and terrain of the mines. Note that the miners work without contracts, social security and or even health benefits.

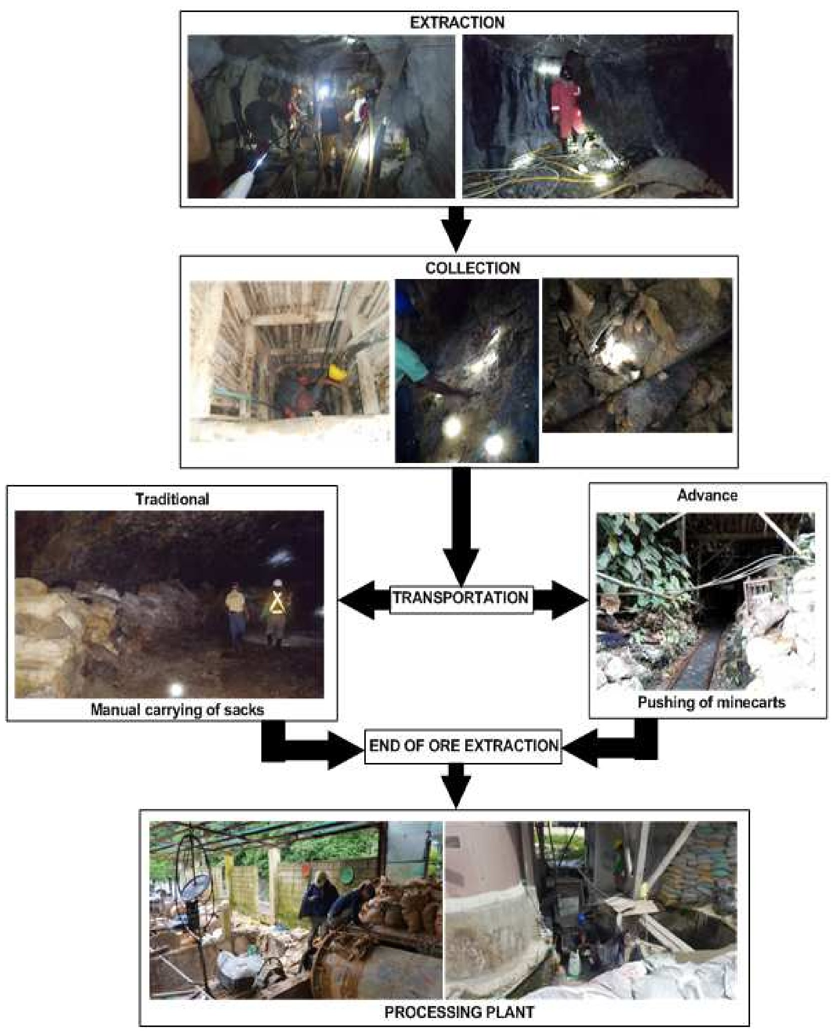
On the other hand, GPP workers work for 1–7 days per week based on work demand, volume of ore, schedule and duration of processes. These do not only influence the number of workdays (1–7 days), but the working hours (1–72 hours) when workers are needed to operate the plants.

4.2 Overview of SSGM (extraction) and processing

The discussion in this section is based on the results of the KIIs conducted and on the research team's direct observations of the workplaces. The information gathered was then verified through existing literature.

The first step in the extraction of gold mines is digging a tunnel to create a pathway into the rock such that the miners can observe the quality and contours of the land and then determine the location (vein) of the gold mine. Once the location has been determined, the miners then lay out the path of the tunnel. Miners subsequently use an explosive to blast the rock formation and then dig up the formation using hand-held tools such as mallets, chisels and shovels. The miners carry the gold ores (approximately 50 kg of ore) out of the tunnels using wheel carts or by manually carrying them on their heads or shoulders to the ball mill site (Figure 3).

Figure 3. Underground SSGM ore extraction



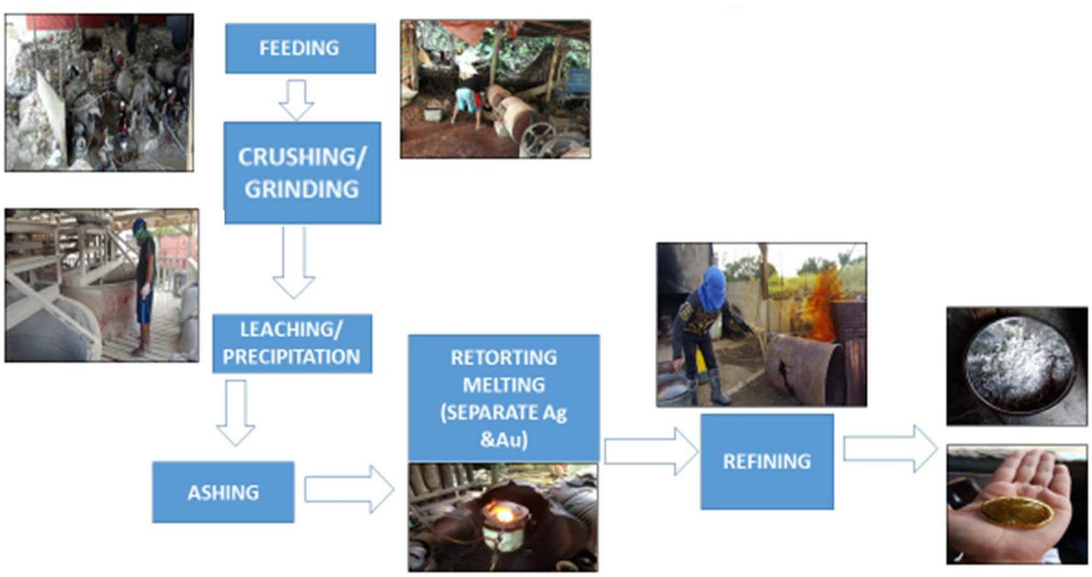
Meanwhile, gold processing mainly involves the following procedures (Figure 4):

a. *Feeding-crushing-ball milling or grinding*. In this process, the run of mine ore is fed to the crushing machine to reduce the size of the ore to about an inch. The next step is ball milling, in which the ore size is further ground to a sand-like ore (usually 200 mesh).

b. *Cyanide leaching/precipitation*. The cyanide leaching and precipitation process usually take 3–5 days to complete. In automated leaching, about 30 kg of cyanide is mixed with 600 m^3 of water inside the agitation or leaching tanks. Granulated carbon and lime are then added to the mixture.

Conventional (manual) cyanide leaching/precipitation is still being practiced at the study sites. The workers immerse the sacks of cyanide in water to dissolve the cyanide, and then store the solution in a metal drum for 5–6 days. After this period, the solution is drained and poured into a drum containing a precipitate bag with zinc dust. The workers repeat this three times until the zinc-gold mixture sticks to the lining or to the precipitate bags, which is then washed thoroughly with water.

Figure 4. Gold processing



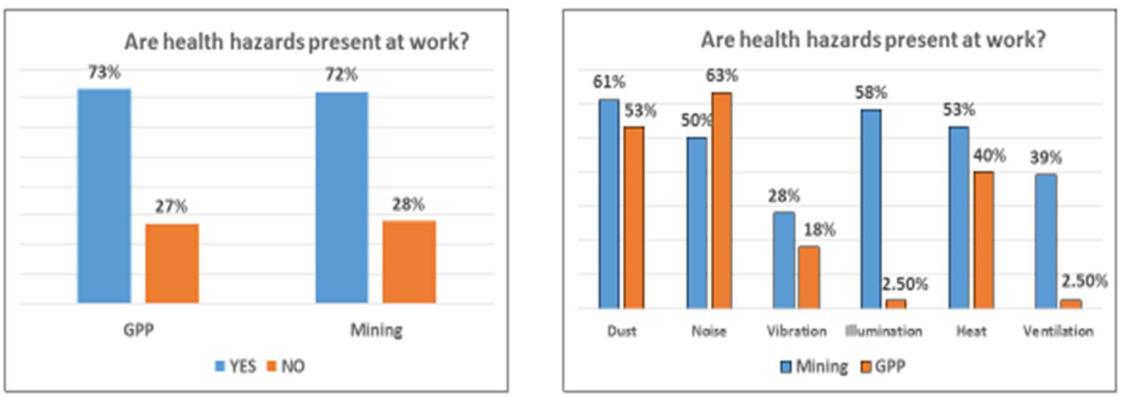
c. *Ashing-retorting-refining*. The collected solid precipitate is dried by heating it over a fire. Thereafter, the workers place the solid precipitate into a clay pot, and then mix it with borax (sodium borate). The borax-precipitate is heated under high temperature until the mixture melts completely. The molten mixture is cooled in a basin of water and then reheated inside the clay pot. The molten mixture is poured into another container that contains water. The workers stir the mixture continuously until a black composite of impurities appear. The impurities are discarded, leaving only the silvery particles behind. The workers heat nitric acid continuously and then add the acid to the silvery particles until a range vapour appears. Borax is added again into the residue and then re-heated to further remove the impurities and until a gold nugget is obtained.

4.3 Perception of workers on occupational safety and health

Majority of the miners (31 out of 50) and GPP workers (40 out of 50) believe that their workplaces have potential health hazards. Among the highly recognized physical hazards in both GPP and UMs studied are noise, heat and vibration.

Generally, miners and GPP workers have totally opposite views regarding the OSH hazards present at their workplaces (Figure 5). However, contrary to what the GPP workers think, the miners perceive inadequate lighting and ventilation as health hazards due to the confined condition underground, where the source of natural light and natural ventilation are limited or none at all.

Figure 5. Perception on health hazards in SSGM and GPP



Note: GPP = gold-processing plant.

About 43 per cent and 24 per cent of the GPP and UM workers, respectively, use chemicals. However, only 36 per cent of chemical users in the GPPs believe that chemicals are hazardous. On the other hand, 72 per cent of the miners using chemicals perceive chemicals as a hazard.

4.4 Health hazards

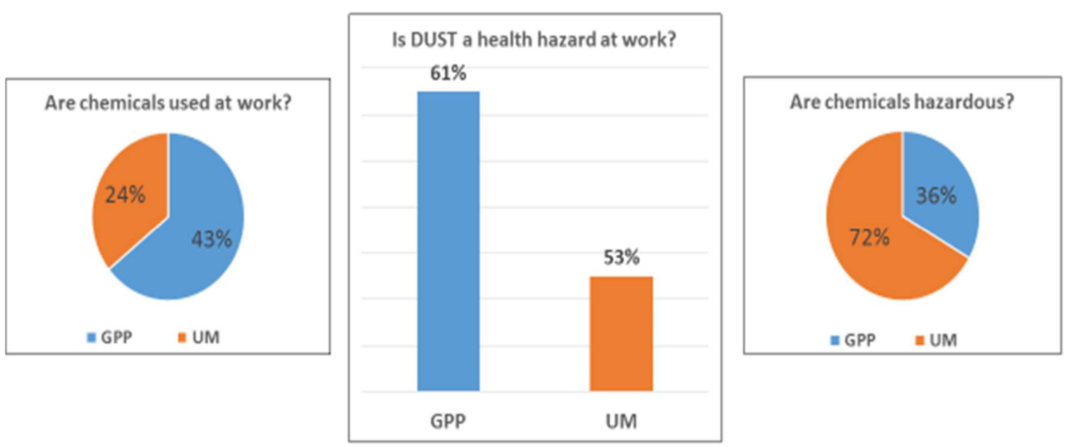
The results of the direct observation of work areas, processes and practices of workers identified the following physical hazards: noise, vibration, inadequate illumination, ventilation and heat stress. Note that the workers identified all of these factors as health and environmental hazards. Likewise, the literature review in the previous chapter has established these hazards in almost all of the studied SSGM sites.

On the other hand, the workers at the study sites are also exposed to various chemicals used in gold processing, the most common of which are borax, lime powder, carbon, sodium cyanide and nitric acid. In some small UMs assessed, the workers use ammonium nitrate and fuel oil. The workers place these chemicals inside small "iced candy" plastic bags (1.5 in × 12 in) and then used to blow up the ground. They also claim to use dynamites, similar to what large-scale miners use. However, most of their processes are done manually; they also use diesel and gasoline (oil/grease) for their machines (for example, generators, electric power for blowers, drillers, and so on).

Although the government prohibits the use of mercury, some SSM still use it illegally. They are often placed in used beverage containers (without labels) that can be bought even from small stores; they are stored in various places of the house (sometimes, placed among condiments and even inside a sack of rice).

Based on the nature of exposure, GPP workers are exposed to different chemical hazards: dust during handling of ore and powdered chemicals (borax, silver nitrate, carbon and lime); heavy metals (mercury); organic vapours (diesel, gasoline); mist and fumes (cyanide, nitric acid); and different gases coming from the exhaust fumes of vehicles and equipment. Figure 6 details the perceptions of UM and GPP workers with regard to the chemical hazard at their workplaces.

Figure 6. Workers perception of chemical hazards in GPPs and UMs



Note: GPP = gold-processing plant, UM = underground mine.

4.5 Work environment measurement (WEM)

The previous section identified the health hazards present in GPPs as perceived by the miners and GPP workers. This section discusses the evaluation results of the chemical and physical hazards the workers are exposed to. Specifically, the research assessed the workers' exposure to dust, cyanide, nitric acid and some gases present at the workers workplaces. The research team also measured the physical hazards at the workplaces such as noise, illumination, heat and ventilation that may potentially affect workers health.

4.6 Chemical hazards

Dust. The ores extracted during mining contains silicates. Accordingly, the team monitored the workers' exposure to silica dust by collecting samples from the ball/rod mill areas of nine processing plants that were operating at the time of measurement. Sampling was done through a filtration technique that uses a collection device attached near the workers' breathing zones. The collected samples were then analysed at the OSHC laboratory using the gravimetric method. Specifically, the ore samples were analysed by the Philippine Accreditation Board Certified Testing Laboratory through gravimetric and x-ray fluorescence for per cent concentration of crystalline silica in ores. The results of the analysis were further evaluated based on the TLVs. The TLVs are computed based on the per cent silica content of ore, the formula of which is provided by the OSHS-DOLE.

Based on the results of the measurements, the workers' exposure to total and respirable airborne crystalline silica have exceeded the TLVs at concentrations greater than the recommended TLVs (Table 1).

Borax, which is a common smelting chemical in powder form can be a major source of dust exposure among workers who directly handles the chemical. The results of the personal dust monitoring (that is 3.21 mg/m^3 for total dust and 2.41 mg/m^3 for respirable dust) do not exceed the TLVs of 5 mg/m^3 and 10 mg/m^3 for respirable and total dust, respectively, based on the OSHS-DOLE. Despite these results, exposure to borax at 4 mg/m^3 or more and infrequent exposures of 1.1 mg/m^3 can cause symptoms of acute respiratory irritation such as dryness of the mouth, nose or throat, dry cough, nose bleeds, sore throat, productive cough, shortness of breath and chest tightness (Gabrant, et al., 1985). Moreover, handling other chemicals in powder form (such as lime, silver nitrate, carbon, and so on) are also potential sources of workers dust exposure.

Table 1. Results of dust measurement in GPP

Workers' activity	Processing plants	Concentration of dust (mg/m³)				
		Total dust (mg/m³)		Respirable dust (mg/m³)		% Silica
		EC	TLV	EC	TLV	
Ball mill operator	GPP1	3.61	0.347	1.17	0.117	83.33
Ball mill operator	GPP4	3.21	0.586	2.41	0.199	48.17
Ball mill operator	GPP12	2.15	0.491	1.69	0.166	58.06
Ball mill operator	GPP13	2.56	0.512	1.54	0.174	55.54
Ball mill operator	GPP15	5.33	0.451	3.50	0.153	63.45
Ore feeding	GPP1	4.45	0.348	2.91	0.117	83.33
Ore feeding	GPP15	10.29	0.451	6.18	0.173	63.45
Ore feeding	GPP16	13.33	0.471	8.00	0.159	60.71
Borax mixing	GPP11	3.21	10.000	2.41	5.000	0.00

Notes: (1) The exposure concentration presented in this table is based on the results of the measurements.

(2) Total dust refers to all fraction of dust.

(3) Respirable dust refers to the fraction of the total dust that passes through a selector. The size of the selector size is 7 microns or less in diameter and this can be inhaled or deposited into the lungs.

(4) TLVs are computed based on the per cent silica content of ore.

(5) The following formula are used to compute for the applicable TLV used to evaluate silica dust:

For total dust concentration: $TLV = \frac{30\ mg/m^3}{\%\ SiO_2 + 3}$

For respirable dust concentration: $TLV = \frac{10\ mg/m^3}{\%\ SiO_2 + 2}$

(6) EC = exposure concentration
GPP = gold processing plant
TLV = threshold limit values

(7) Not all of the GPPs were fully operating at the time the research team conducted the measurement; thus, only 7 GPPs out of the 16 total GPPs surveyed were assessed for dust exposure.

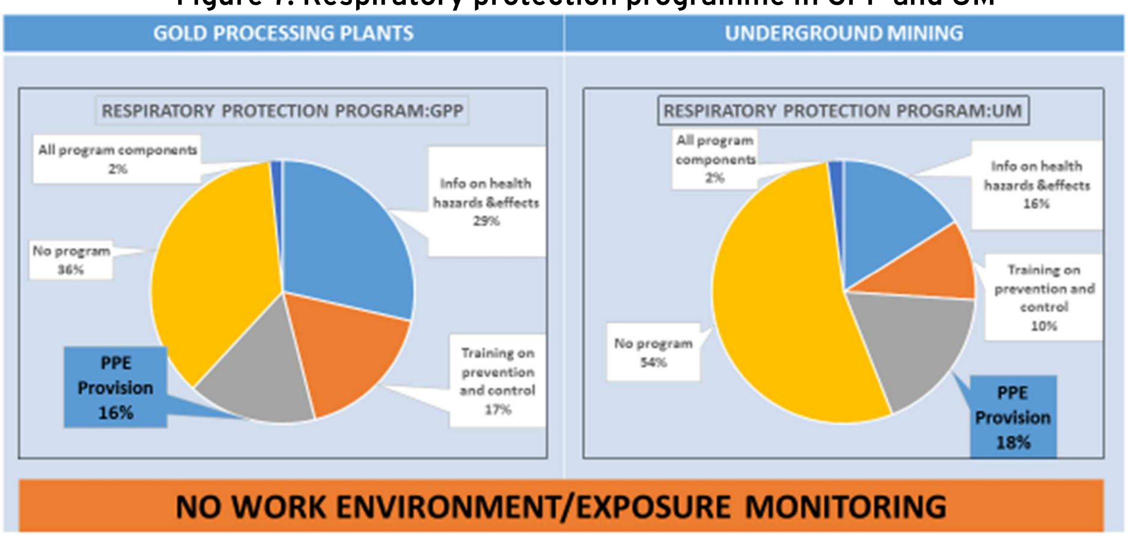
The underground miners recognize that exposure to dust is a health hazard. However, inasmuch as the research team wanted to monitor the underground miners' dust exposure, some factors limited the researchers from doing so. Nevertheless, the presence of high concentrations of silica in ore, which is the dust generated from underground operations (for instance, blasting and drilling/digging), and the presence of dried ores on the workers bodies, tools and PPEs can expose workers to high concentrations of silica dust through inhalation.

Although majority of the workers perceive dust as a health hazard, they do not know that being exposed to silica dust is toxic and can adversely affect their health. This is the primary reason why appropriate respiratory protective equipment should be used when performing dusty activities.

The results of the survey of the respiratory protection programme,[9] one of the risk-based programmes to address workers' exposure to chemicals, showed significant findings regarding SSGM workers risk exposure. In particular, the results show that 16 per cent and 18 per cent of the workers in GPPs and UM, respectively, do not use appropriate respirators; instead, they use t-shirts tied around their faces as improvised nose and mouth covers.

Likewise, the SSGM sector's compliance with the other components of the respiratory programme is very low. Such respiratory programme components include trainings on prevention and control of exposure, dust control and other programme components to control or minimize workers' exposure to dust and other chemicals. Based on the results of this study, about 36 per cent and 54 per cent of the respondents in the GPPs and UMs, respectively, claim that not even one component of the respiratory protection programme is being implemented at their workplaces. However, some of the programme components are being implemented in both the GPPs and UMs of mining permittees included in the MGB's *Minahang Bayan* and through local government's initiatives (in fact, one of them was a *Galing Pook* awardee). Moreover, 100 per cent of the respondents affirm that no WEM has ever been conducted at their workplaces (Figure 7).

Figure 7. Respiratory protection programme in GPP and UM



Note: GPP = gold-processing plant, PPE = personal protective equipment
UM = underground mine

The risk of silicosis has long been a serious hazard in mining. The prevalence of this disease among miners remains a problem in the mining industry, particularly in developing countries like the Philippines. As already discussed in the previous chapter,

[9]The major route of the workers' exposure to dust and chemicals is through inhalation. Thus, mining companies should have respiratory protection programmes.

prolonged exposure to crystalline silica can also cause chronic obstructive pulmonary disease and risk of lung cancer. In fact, one of the officials interviewed in this study claim that the incidence of respiratory diseases in the area have been increasing over the years, and this can be attributed to the people's exposure to silica dust. Some miners have reported that they suffer respiratory diseases and had been accordingly diagnosed to have tuberculosis. However, the body of evidence that shows the extent of silica dust-related respiratory diseases among workers and mining communities in the Philippines are limited. This is primarily due to the limited number of experts who can appropriately diagnose and provide heath interventions for the disease.

Cyanide is known to be toxic to humans. It is also often suggested to be a comparable substitute to mercury. However, despite its toxicity, this chemical compound is still commonly used in industrial gold mining.

The research team conducted personal and area monitoring at the research sites using sampling pumps, with flowrate set at 1 litre per minute. A minimum of two sampling points were placed in the agitation/mixing/cyanide leaching process area for area monitoring.

On the other hand, the researchers attached a sampling device near the workers breathing zones for the personal monitoring. Following the modified and validated procedure prescribed by the US NIOSH (Eller and Casinelli, 1994), the samples were collected, stored, transported and analysed at the OSHC laboratory using UV-VIS spectrophotometry.

According to the OSHS-DOLE, the results of the area and personal sampling at the ten sites monitored did not exceed the TLV of 10 ppm (Table 2). The low results may be due to the time when the samples were collected, which was after the workers had prepared and loaded the cyanide into the agitation/leaching vats. The loading of cyanide into the agitation/leaching vats had been conducted 2–3 days prior to the measurement. The exposure concentration of workers to cyanide was expected to be highest during the agitation/leaching process. For one, the workers monitor the leaching process. For another, the "chemist" (worker assigned in chemical analysis)[10] is directly exposed to the cyanide emitted from the open tanks during continuous agitation and during the pH testing of the mixture.[11] The cyanide had been loaded into the agitation or leaching vats 2–3 days prior to the conduct of measurement.

[10]Based on the interviews, even the "chemist" was not aware of the possible adverse health effects of cyanide exposure.
[11]pH testing is performed to ensure that the mixture it is strongly basic (over pH 10.5).

Table 2. Results of hydrogen cyanide measurement in GPPs monitored

Processing plant	Concentration (ppm)	Processing plant	Concentration (ppm)
Area monitoring[3]			
GPP1	0.0085	GPP 11	0.0064
GPP2	0.0304	GPP 11	0.0012
GPP2	0.2530	GPP 12	0.0152
GPP3	0.0750	GPP 12	0.0069
GPP 4	0.1385	GPP 13	0.1358
GPP 4	0.1552	GPP 13	0.1267
GPP 8	0.0725	GPP 13	0.1324
GPP 8	0.0987	GPP 13	0.1345
GPP 10	0.0614	GPP 16	0.0920
GPP 10	0.0628	GPP 16	0.1000
Personal monitoring[4]			
GPP1	0.0147		
GPP4	0.0638		
GPP16	0.0890		

Notes: (1) TLV is based on OSHS-DOLE: 10 ppm.
(2) GPP = gold-processing plant
DOLE = Department of Labor and Employment
OSHS = Occupational Safety and Health Standards
ppm = parts per million
TLV = threshold limit values
(3) Not all of the GPPs were fully operating at the time the research team conducted the measurement; thus, only six GPPs out of the 16 total GPPs surveyed were measured for hydrogen cyanide.
(4) The sampling technique used depended on the personal judgement of the industrial hygienist conducting the WEM. Personal monitoring was not applicable in the other sites where the area monitoring was conducted. Likewise, area monitoring was not conducted in GPP 16.

The agitation/leaching area is semi-open; thus, it could be expected that the natural air had already removed the cyanide in the work area at the time the measurement was done. Therefore, given the conditions of the sampling, cyanide gas could still be detected even at low concentrations, which could be due to its density (0.687 g/mL). Cyanide gas is lighter than air and is easily dispersed in air with adequate ventilation.

It can then be deduced that the exposure of the workers who are directly engaged in the agitation/leaching processes is much higher when they are loading the cyanide into the agitation/leaching tanks. Hydrogen cyanide can easily be absorbed through various route of entry. Short-term exposures to low levels of cyanide via inhalation, skin absorption or ingestion can lead to the following symptoms in a matter of minutes:

rapid breathing and heart rate, restlessness, dizziness, weakness, headache and nausea/vomiting (MDCH, 2004).

Nitric acid monitoring was also carried out in this study. The research team used sampling pumps with flowrate of 1 litre per minute to conduct the area and personal monitoring. In the area monitoring, a minimum of two sampling points at the workers position were done while an air sampling device was attached near the breathing zone of the workers in the refining area. Following the NIOSH procedure, the samples were collected, stored, transported and analysed at the OSHC laboratory using UV-VIS spectrophotometry.

The working conditions at the different refining areas vary from being enclosed, semi-enclosed and open. Based on the results of the measurement, the concentration of nitric acid in all conditions did not exceed the TLV of 2 ppm (Table 3). However, those measuring points that are closer to the source (where the refining is performed), including the personal exposure of workers at GP16, exceeded the action level[12] of 1 ppm. The "red fuming nitric acid" with suffocating odour, an evidence of the presence of high concentration of nitric acid, was observed in the areas with action-level results.

Table 3. Results of nitric acid measurement in the GPPs

Processing plant	Workplace condition	Measuring point	Concentration (ppm)	Evaluation
Area sampling				
GPP2	Enclosed with "hood"	Near source	0.0929	P
GPP2			0.0860	P
GPP4	Enclosed		0.2196	P
GPP4		Near source	1.0091	AL
GPP11	Open		0.4498	P
GPP11		Near source	1.2036	AL
GPP16	Open		0.6410	P
GPP16		Near source	1.3040	AL
Personal sampling				
GPP4	Enclosed		0.3396	P
GPP11	Open (outside)		0.2006	P
GP16	Open (outside)		1.7170	AL
TLV based on OSHS-DOLE			2 ppm	

Notes: (1) P (passed) – concentration that did not reach the action level or exceeded the TLVs.
AL (action level) – concentration or exposure level that reached 50 per cent but not more than its TLV.
(2) Not all GPPs were conducting the refining process during the time of measurement. Thus, only a number of GPPs was monitored out of the total 16 GPPs.

[12]Action level means the concentration of chemicals is >50 per cent, but not exceeding the TLV.

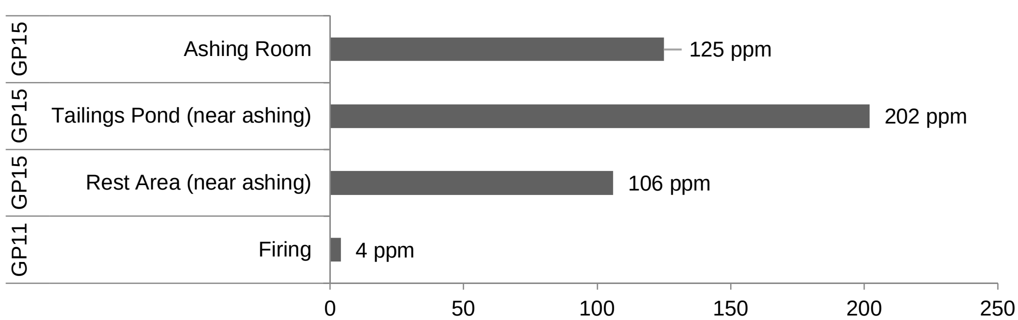
The results presented in Table 3 suggest that the refining process performed even in open areas does not guarantee the workers protection against chemical exposure. Being in open areas is not enough to ventilate and dilute the contaminants due to the inconsistent air velocity and direction, particularly when the vapour density of the chemical such as nitric acid (1.513 g/cm^3) is heavier than air.

Local exhaust ventilation is a proven engineering control to prevent workers from being exposed to contaminants. Although non-conclusive, the very low concentration of nitric acid (<0.1 ppm) at the enclosed GPP2 suggest that the retorting/refining process performed in the hood helped to remove the contaminant from the source.

Although using nitric acid in the refining process is not performed on a regular basis, it is still very toxic if inhaled; it is also corrosive to human tissue. Prolonged exposure at low concentrations and short-term exposure to high concentrations of nitric have serious adverse health effects on humans. As previously discussed in the literature review, concentrated nitric acid and its vapours are highly corrosive to the eyes, skin and mucous membranes. Exposure to high concentrations of the chemical can cause asphyxiation due to swelling throat swelling and pneumonitis and lung oedema when the fumes coming from high concentrations of nitric acid are inhaled. Meanwhile, repeated or prolonged inhalation may result in tooth erosion, chronic inflammation of the respiratory tract and reduced lung function.

Carbon monoxide and other gases. Different kinds of gases, such as carbon monoxide (CO), hydrogen sulphide (H_2S), volatile organic compounds (VOC) and combustible gas (methane) were also measured at the GPPs and UM sites using a direct read-out calibrated multi-gas monitor. Based on the measurement results, CO was the only gas detected from 2 of the 16 GPPs monitored. However, the results were alarming; CO concentration levels of 106–202 ppm were monitored at GPP 15 during charcoal ashing, which exceeds the TLV of 50 ppm (based on OSHS-DOLE). On the other hand, CO at 4 ppm concentration was detected at GPP 11 during firing (Figure 8).

Figure 8. Measurement of CO in GPPs monitored



The high CO concentrations detected at the sites are reliable evidence of incomplete combustion of charcoal, a carbon-based material used for ashing to recover gold. CO is slightly lighter than air (0.97 kg/m^3 and 1.00 kg/m^3, respectively); it diffuses evenly throughout an enclosed room or diffuses outside with air. Thus, the CO generated from the semi-enclosed ashing room diffuses freely into the air, thereby reaching the tailings pond and rest areas. Timko and Derick (1995) have cited that CO concentrations can change depending on the ventilation rate and the corresponding ventilation pressures at a particular location.

Meanwhile, CO, H_2S, VOC and methane (CH_4) were not detected or were below the detection limit in the 14 UMs monitored. This may be because of the limited mining activities at the time of monitoring.

The workers at the UM sites use mechanical ventilation through blowers, which are usually positioned at the entrance of the tunnel. This serves as the main air supply to remove or dilute the contaminants to safe levels. However, whether this mechanism serves to achieve its purpose cannot be determined because the researchers were not able to conduct area monitoring of the sites.

O_2 is typically not considered a contaminant. However, when its level reaches below 19.5 per cent, such condition can cause asphyxiation or hypoxia in humans. This means that the deficient amount of O_2 reaching the body can cause giddiness, mental confusion, loss of judgment, loss of coordination, weakness, nausea, fainting, loss of consciousness and even death.

The results of the O_2 monitoring show that the O_2 levels in the different UM sites range from 19.6 per cent to 21.3 per cent, which is still within the recommended 19.5–23.5 per cent (as stated in the OSHA 29 CFR 1926.1202). This implies that the probability that the workers will suffer from asphyxiation while inside the UM is low. However, air velocity was insufficient at the sites, and the normal O_2 levels obtained from the UMs can be attributed to the non-detectable concentration of oxygen-depleting gases (namely, CO, H2S, VOC, CH_4) at the time of measurement (Table 4).

Table 4. Summary of gas measurement: UMs

UM Sites	AT 25°C-33°C	RH 78%-99%	O_2 19.6%-2.0%	CO < 1 ppm	H_2S < 1 ppm	VOC ND	CH_4 0
TLV, OSHS-DOLE Reference: OSHA 29 CFR 1926.1202			19.5-3.5%	50	10		

Notes:
AT = ambient temperature
CO = carbon monoxide
CH_4 = methane
CFR = Code of Federal Regulations
DOLE = Department of Labor and Employment
H_2S = Hydrogen sulphide
ND = not detected
O_2 = oxygen
OSHS = occupational safety and health standards
OSHA = occupational safety and health administration
ppm = parts per million
RH = relative humidity
TLV = threshold limit value
UM = underground mine
VOC = volatile organic compounds

The miners claim that the gas emitted by the rotten wooden timbers used as supporting beams underground, had caused the recorded fatalities of miners inside the tunnels. They also believe that if the flame lamp they use inside the tunnel does not burn, then this indicates that the level of gas inside the tunnel is high enough to kill them. This “myth”, as claimed by the old and modern miners alike, can be supported scientifically. Biological oxidation (such as, rotting mine timbers) increases CO_2 and nitrogen (N_2) in the air. These replace the O_2 content inside the mines which results into a toxic atmosphere. This mixture of unbreathable gases is the key component of black damp (also known as *stythe* or *choke damp*); it is an asphyxiant that reduces the available O_2 content in the air to such level that can no longer sustain human or animal life (Hendrick and Sizer, 1992). The same reason also explains why a flame lamp will not burn in such an atmosphere. However, although using black damp to indicate the concentration of asphyxiant gases (namely, CO_2, N_2) may be useful, the miners lack of awareness of the hazards and the lack of proper tools to measure the actual concentration inside the mines can put the underground miners’ lives in danger. Note that an O_2-enriched underground environment at levels above 23 per cent may cause fire and explosion; the ignition source may come from any hazardous energy sources (for example, electrical, mechanical, hydraulic, pneumatic, chemical or thermal sources).

Therefore, the concentrations of O_2 and combustible materials must be constantly monitored to ensure the miners’ safety. Safety engineers need to ensure that the oxygen levels remain within the acceptable range. Likewise, the levels of the combustible materials should not reach higher than 10 per cent of the lower explosive limit while there are people working inside confined spaces such as UMs. Note that although Rule 153 of DENR AO No. 97-30 mandates mining companies to ensure “allowable limits of gases in the mine air” at all times, the miners interviewed said that no gas monitoring has ever been conducted in the UMs. Moreover, as stated in the Order, the required O_2 level of "not less than 20 per cent" maybe confusing if it matters workers protection.

Other chemicals or chemical-related hazards. Apart from the actual measurements, it is important to consider other factors that contribute to the workers' exposure to harmful chemicals. Trainings and safety data sheet of chemicals should be provided to workers to empower them with the knowledge of the potential hazards and ill effects of the chemicals they use. Likewise, the workers shoud be provided with trainings on exposure prevention and control. However, these are not provided or not accessible (kept in cabinet) in most of the study areas. The research team also observed improper handling and storage of chemicals and use of inappropriate PPEs among the workers (Table 5).

Table 5. Other observed chemical-related hazards

Chemical-related hazards (work practice, handling and storage)
Chemical users are not trained on the safe use of chemicals and are not informed of their toxic effects.
No safety data sheet posted or accessible in areas where chemicals are used.
Improper handling of chemicals.
Chemicals are stored in used beverage containers and are not labelled properly.
Open chemical containers.
Deteriorated/corroded chemical containers.
Improper storage of chemicals (chemical storage room).
Containers of corrosive chemicals are stored directly on the floor.
Compatibilities of chemicals are not considered.
Insufficient ventilation inside the chemical storage room.
Mixing/leaching tanks are not covered.
Poor housekeeping at the mini-assay laboratory in agitation/leaching area.

4.7 Physical hazards

Noise. Both GPP and UM workers recognize that noise is a health hazard. Measuring the workers' exposure is the most important part of a workplace hearing conservation and noise control programme. Area monitoring also helps to identify the work locations or processes that have noise levels that may affect the exposed workers.

In this study, noise measurement was conducted using a calibrated integrating sound level; the sound pressure level was determined to indicate the workers noise exposures. Other factors — sources of noise, the times when the sources are operating, the types of noise produced (that is, continuous, intermittent and impulse), and the location and exposure time of workers — were also considered in the measurement. Since majority of the areas monitored were semi-open with considerable air movement, the research team used wind shields or wind screens to cover the microphone and to avoid the effect of wind that may alter the noise reading.

Noise monitoring was conducted at the ball/rod mills, agitation/mixing/leaching areas and at the firing and refining areas of the 16 GPPs. The team identified the pumps and the motors of the ball/rod mills and agitation/mixing tanks as the major noise sources. Likewise, the processes of blow torching or retorting were also identified as sources. The number of noise measuring points per GPP monitored was based on the number of machines operating, number of workers in the area, and the position of exposed workers while performing his task. The workers are assigned per area, and the tasks are likewise divided into defined activities. Likewise, the noise levels are relatively stable all the time. Thus, the noise area monitoring can already represent personal exposure.

The firing or blow-torching processes generated intermittent type of noise, which resulted in noise levels ranging within 85–97 dBA. The noise level that exceeded the PNEL (92–97 dBA) while the workers were doing these processes was taken from an enclosed refining area. On the other hand, the blow torching processes that had been performed in an open or semi-open area had noise levels of 85–89 dBA (Table 6).

The research team evaluated the noise levels based on the workers' exposure time, as provided in the PNEL prescribed by the OSHS-DOLE. For the purpose of this study, the research team used the threshold value of 90 dBA. This means that no worker should be exposed to this level of noise for eight hours a day even if the workers use hearing protection gears. The action level for noise, set at 85 dBA, was also used in the evaluation. Action level is defined as the noise exposure level at which employers are required to take certain steps to reduce the noise (through engineering control) to a level that will not harm the workers (Health and Safety Executive, 2017). Accordingly, practicable measures through administrative controls and prescribing the use of hearing protection must be strictly implemented to minimize the workers noise exposure at the workplaces.

Noise exposure should be evaluated based on the actual exposure time of the exposed worker. However, GPP operations are irregular or on a per-demand basis. Thus, the researchers could not establish the time of exposure to be able to compare the actual values with the PNEL. This means that the data collected could not be used to directly compare with the action level of 90 dBA for eight hours exposure as provided in the OSHS. Most of the noise levels monitored reached or exceeded the action level of 85 dBA; thus, it can be deduced that the workers are exposed to noise. As such, exposure to such levels must be controlled, and the workers should be appropriately and adequately protected.

Table 6. Noise levels (in dBa): GPPs

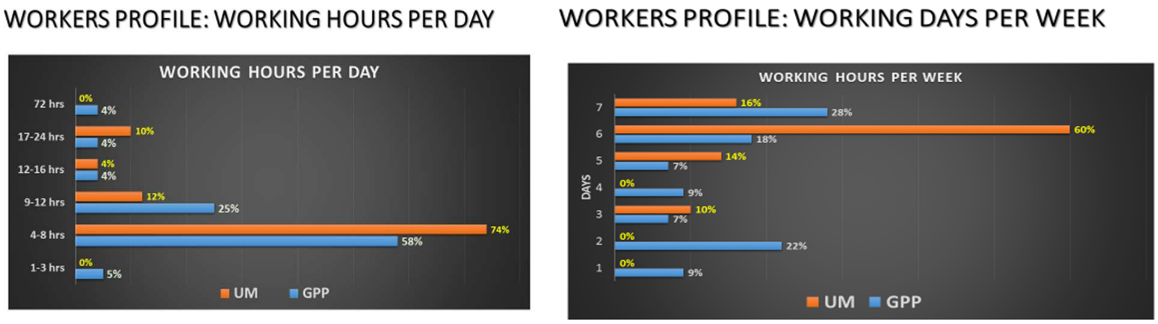
		Agitation/Leaching		Firing		Ashing	
GPP	Noise level	GPP	Noise level	GPP	Noise level	GPP	Noise level
GPP1	97	GPP 1	89	GPP 1	92	GPP 4	79
GPP 1	97	GPP 1	89	GPP 1	97	GPP 4	79
GPP 5	78	GPP 2	101	GPP 3	89	GPP 15	89
GPP 5	87	GPP 3	77	GPP 15	87		
GPP 8	99	GPP 4	80				
GPP 8	95	GPP 4	82				
GPP 9	87	GPP 4	82				
GPP 13	99	GPP 12	67				
GPP 13	100	GPP 12	67				
GPP 14	80	GPP 12	64				
GPP 15	91	GPP 13	84				
GPP 15	87	GPP 15	81				
GPP 15	82	GPP 15	80				
GPP 15	89						
GPP 16	92						
GPP 16	91						
GPP 16	94						
GPP 16	94						
GPP 16	93						

Notes: (1) Permissible noise exposure levels are based on OSHS-DOLE: 90 dBA.
(2) The values in blue refer to the action level for noise, which is 85 dBA. The values in red mean that the values exceeded the PNEL 90 dBA.
(3) Not all of the GPPs were fully operating at the time the research team conducted the measurement; there were no sources of noise because there were no processes being conducted. Thus, not all 16 GPPs were measured for noise levels.

The WHO (2016) has reported that many of the processes conducted in SSGM (for instance, extraction, crushing and milling) are associated with elevated occupational noise levels. Such levels exceed the guideline limits for preventing noise-induced hearing loss.

Majority of the mine workers (74 per cent) work in the UMs for 4–8 hours a day, six days per week (60 per cent) (Figure 9). Thus, their exposure to noise from various sources should be identified. However, the research team was constrained by the tunnel conditions during the data gathering period; thus, only the noise during blasting, which reached the ceiling value of 115 dBa was obtained.

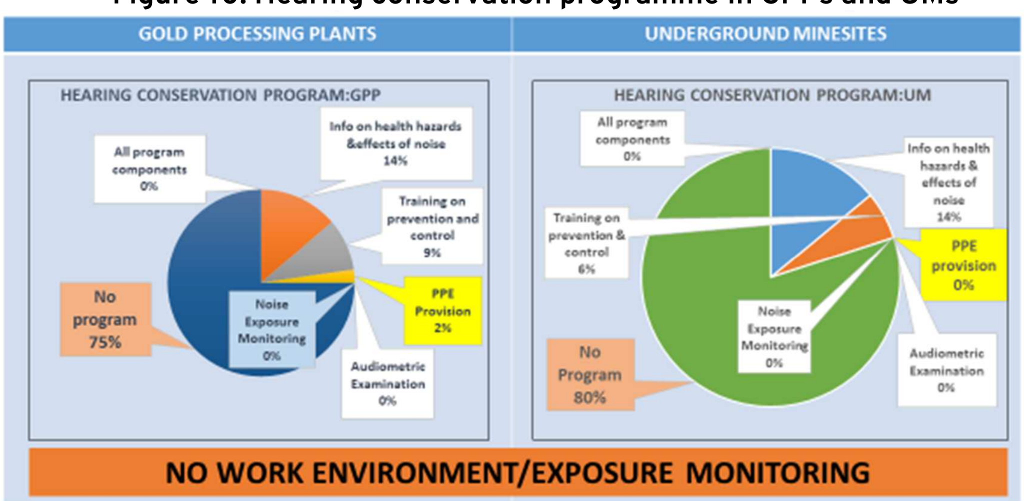
Figure 9. GPP and UM workers working hours per day and days per week



Small-scale miners first line of defence from the noise generated during blasting is to use hearing protective gears. However, not even a single worker directly engaged in noisy processes was wearing adequate hearing protection. One miner was seen using cotton balls for his ears in order to protect himself from the noise. Several studies on gold processing and SSM's compliance with PPEs do not include compliance with hearing protection.

The same findings were obtained during the interviews conducted at the Hearing Conservation as one of the risk-based programmes considered in this study. Only 2 per cent of GPP workers interviewed said that their employers provide them with hearing protection, 14 per cent claimed that they have been informed on the hazards and ill effects of noise, and 6–9 per cent have been provided with training on prevention from and control of noise exposure. However, noise exposure monitoring and audiometric examination of the exposed workers have not been conducted in both the GPPs and UMs visited. Moreover, 75–80 per cent of the respondents claimed that they do not have any hearing conservation programme (Figure 10).

Figure 10. Hearing conservation programme in GPPs and UMs



It is remarkable that AO No. 97–30 never mentions in any of its provisions that noise is a potential hazard; thus, employers are not mandated to establish a hearing conservation programme.

Heat stress. Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment (Parsons, 2010). Due to the physiological and psychological differences of individuals, the environmental conditions required for each individual are different. Hence, the industrial hygiene approach provides a thermal environment that satisfies the majority of people in the workplace where four basic environmental variables (temperature, radiant temperature, humidity and air movement) and behavioural factors (clothing and the metabolic rate) are considered.

UM and GPP workers are exposed to extreme heat or work in hot environments, especially those in the tropical regions like the Philippines. At-risk workers include miners and gold-processing workers who work around heat-generating operations. Thus, 53 per cent (27 out of 50) and 40 per cent (22 out of 55) of the study populations in UMs and GPPs, respectively are considered at-risk.

The GPP workers heat gain is due to a combination of external environment heat exposure sources: weather-related and man-made heat exposure and internal body heat generated from metabolic or manual processes. The workers who perform retorting and refining activities are exposed to both outside and internal heat sources.

Despite the absence of direct solar heat in the enclosed retort/refining areas of GPP1 and GPP4, the results of this study's heat measurement show that the heat coming from the refining process may not have been exhausted as indicated by the "failed" (GPP4) and "action limit" (GPP1) results in Table 7. The "failed" result means that the value has exceeded the wet-bulb globe temperature (WBGT) index[13] recommended by the ACGIH. On the other hand, the "failed" result in GPP16, the only GPP that conducts refining in an open area, was not expected because there was natural ventilation at the site. However, the "failed" results may be due to the internal body heat load resulting from the workers physical and strenuous activity during the gold-refining process, which consequently increases the workers metabolic rate. Thus, the radiant heat load may have worsened the workers heat stress at GPP 16, thereby resulting in the "failed" measurement.

[13]The wet-bulb globe temperature (WBGT) index measures the heat stress under direct sunlight. This accordingly considers temperature, humidity, wind speed, sun angle and cloud cover (solar radiation). The WBGT index is different from heat index as the latter considers temperature and humidity; likewise, heat index is calculated for shady areas (NOAA, 2019).

Table 7. Results of WBGT (heat) measurement

GPP	WP condition	Weather	RH (%)	AT (°C)	WBGT index (°C)	Evaluation
GPP1	Enclosed	Sunny	81	31	28.5	Action limit
GPP3	Semi-open	Rainy	89	28	31.2	Failed
GPP4	Enclosed	Sunny	79	32	30.8	Failed
GPP11	Semi open	Occ rain	98	29	28.8	Action limit
GPP16	Open	Sunny	53	31	30.9	Failed

Source: OSHA Section III: Chapter 4, Screening Criteria for ACGIH TLV and Action Limit for Heat Stress, Exposure–September 15, 2017.

Notes: (1) The recommended WBGT index for moderate workload of 25–50 per cent work allocation is 30°C, whereas action limit is 27°C.

(2) AT = ambient temperature
GPP = gold-processing plant
WBGT = wet-bulb globe temperature
WP = workplace

(3) Not all of the GPPs were fully operating at the time the research team conducted the measurement; there were no sources of heat because there were no processes being conducted. Thus, not all 16 GPPs were measured for WBGT.

The heat measurement results in the five areas monitored also show that three areas (out of the five areas monitored) exceeded the WBGT index of 31°C**.** Meanwhile, two areas exceeded the action limit (AL) of 28°C for acclimatized workers with moderate workload and 25–50 per cent work-rest allocation based on the 2017 ACGIH standards.

Most researchers use the ACGIH's tables of screening criteria for TLV and AL for heat stress as an initial screening tool for evaluating whether a heat-stress situation may exist at a particular area. This is based on the WBGT, workload, and work/rest regimen (OSHA, 2017). The values in the said tables are more conservative than the TLV or AL values. Likewise, they do not prescribe work and recovery periods. However, this screening tool is helpful for evaluating heat stress and strain.

The major heat sources in the UMs are strata heat (geothermal gradient), auto-compression and mining equipment. The increase of strata temperature with depth is known as the "geothermic gradient"**.** On the average, the temperature increases by about 25°C for every kilometre of depth (Hanania, et al., 2019). On the other hand, heat is gained as the descending air gets compressed by the columns of air (air auto-compression). Air auto-compression for ventilation adds about 6°C dry bulb temperature per 1,000 metre of vertical depth (Kamali-Zare and Nicholson, 2013).

The research team did not perform actual WBGT measurement in the UMs due to the equipment's limitation to wet environments and due to the limited use of machinery in the monitored UMs. However, since the workers comfort from the natural heat sources (that is, geothermal gradient and auto-compression) can be addressed by the mine ventilation system, the team measured the air velocity inside the UMs instead (Roghanchi, 2017). The results show that air velocity decreases as the measuring point get farther and deeper (Table 8). Thus, the "failed" results of the ventilation measurement means that thermal comfort in the UMs is not being addressed by the SSGM companies monitored.

Table 8. Results of ventilation measurement in UMs

Mine sites	Measuring point		Air velocity
UM1	Point A	Entrance of horizontal tunnel	0.05–0.28
	Point B	300 metres from the entrance	0.50–0.75
	Point C	480 metres from the entrance	0.05–0.15
	Point D	Drive (branch) from point C	0.05–0.12
	Point E	640 metres from the entrance	0.05–0.10
	Point F	Sinking about 60 metres deep	0.05–0.08
UM3	Point A	Pit entry (60 metres vertical entry)	0.50–0.76
UM4	Point A	3 metres horizontal distance (10.6 metres vertical)	0.05–0.15
	Point B	4 metres horizontal distance (10.6 metres vertical)	0.05–0.10
UM5	Point A	Entrance of horizontal tunnel	0.05–0.18
	Point B	Middle of horizontal tunnel	0.05–0.10
	Point C	End of horizontal tunnel	0.05–0.08
UM6	Point B	Horizontal distance 170 metres from tunnel opening	0.15–0.20
	Point C	Horizontal distance 180 metres from tunnel opening	0.05–0.10
	Point D	Horizontal distance 400 metres from tunnel opening	Below 0.05
UM8	Point A	Few metres from tunnel opening	0.28–0.35
	Point B	Horizontal distance 60 metres from tunnel opening	0.15–0.20
UM11	Point A	Entrance of mine site	0.25–0.30
	Point B	50 metres from entrance	0.18–0.20
	Point C	100 metres from entrance	0.10–0.15
	Point D	200 metres from entrance	0.05–0.10
UM12	Point A	Entrance of mine site	0.50–0.74
	Point B	50 metres from entrance	0.10–0.14

Notes: (1) The minimum air velocity standard for enclosed workplace is 0.25 m/sec based on the OSHS-DOLE.
(2) Values in red mean that the value did not meet the minimum air velocity standard.
(3) UM = underground mine
(4) Not all of UMs were at the time of the measurement due to their locations and physical condition (uphill and actual condition underground), which prevented the team from conducting proper research in these areas. Thus, only 8 UMs were monitored here instead of 14.

Occupational exposure to heat can result in injuries, diseases, reduced productivity and even death. Workers who are exposed to extreme heat, work in hot environments indoor or are engaged in strenuous physical activities are at risk of heat stress. Being exposed to extreme heat can result in occupational illnesses caused by heat stress (such as, heat stroke, heat exhaustion, heat syncope, heat cramps, heat rashes) or even death (CDC, 2018). Heat can also increase workers risk of injuries, as it may result in sweaty palms, fogged-up safety glasses, dizziness and can reduce brain function responsible for reasoning ability, thereby creating additional hazards. Other heat injuries such as burns can occur as result of contact with hot surface and steam leak.

Ventilation. Ventilation refers to air movement; it is dependent on the source, volume and direction of the air. Although air ventilation is not directly related to the production processes, the lack of proper ventilation may result in accidents, injuries, and illnesses of workers. Air is not only important for breathing, particularly for miners underground, but it also disperses or dilutes the chemicals (gases, fumes, vapours and dusts) and physical agents (noise, heat and humidity) used in mining processes.

The research team used a test instrument thermoanemometre (Kimo Brand, VT100) to measure the air velocity at different points of the GPPs and UMs. Although ventilation is not critical in the open or semi-open areas of the GPPs (such as, ball mill and agitation/mixing/leaching areas) since natural air moves freely, it is still essential in the processes that involve heat (for instance, torch blowing and refining). As previously discussed, adequate ventilation does not only remove or dilute the airborne contaminants emitted from the process but provide thermal relief for workers.

Based on the measurement results, the air velocity in the ball mill and agitation/mixing/leaching areas met the minimum air velocity standard of 0.25 m/sec. Meanwhile, air velocities of 0.05–0.15 m/sec were measured in the enclosed or semi-enclosed refining/retorting areas, which fail to meet the minimum standard.

Ventilation in enclosed or confined environments such as UMs is very important to the OSH of UM workers. It is crucial for maintaining sufficient quantities of oxygen and for removing or diluting contaminants (dust, toxic gases, and vapours) to acceptable levels. As such, air velocities need to be constantly monitored at different points of the UMs to ensure that air is circulating rather than stagnating. However, as observed in one of the UMs visited, the ventilation system is maintained crudely through the use of fans and blowers. These are lined up by hanging them and by placing them from the mining entrance to the innermost portion of the UM. Although this kind of measure can provide ventilation, it imposes possible electrical hazard due to the long wiring extensions and moist environment inside the tunnel. In addition, the fans and blowers also generated potentially high noise level.

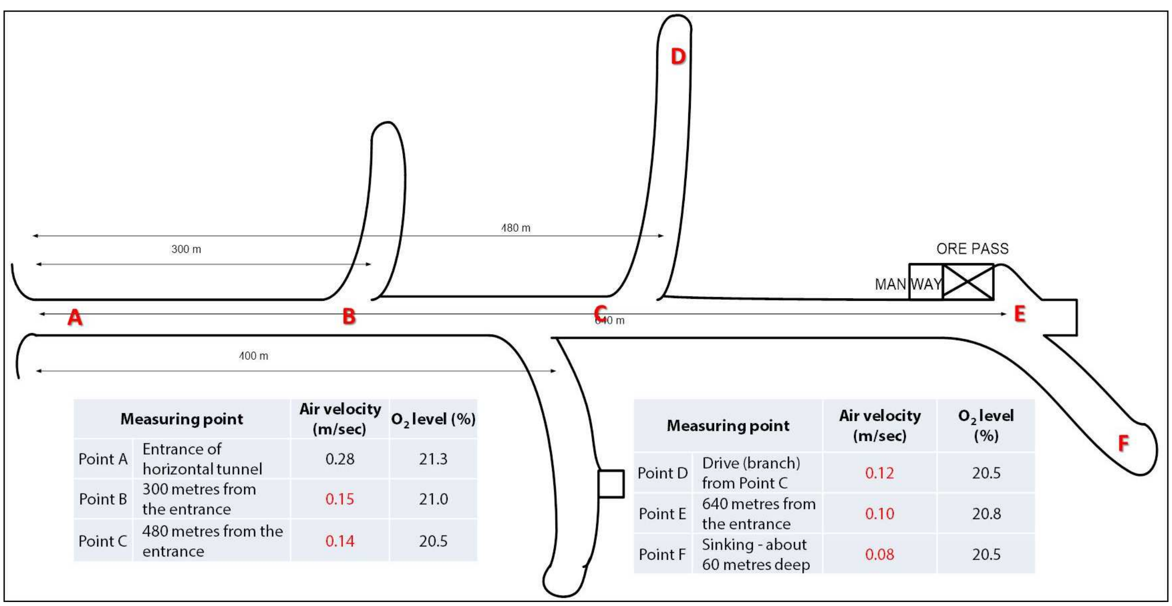
At the time of measurement, the researchers measured adequate air velocities at the entrances of the tunnel (point A), except for the entrances of UM4 and UM5, which has very small openings. Note that air velocity decreases as the measuring point goes farther inside the tunnel opening. Moreover, the results reveal that even with mechanical ventilation system provided, particularly in UM1, air velocity was inadequate to reach the thermal comfort level of workers as prescribed by the OSHS-DOLE (Table 9 and Figure 11).

Table 9. Ventilation measurement results: GPPs

Processing plant	Area	Air velocity	Processing plant	Area	Air velocity
GPP1	Agitation tank	1.24	GPP 14	Ball mill	1.08
GPP 1	Agitation tank	0.92	GPP 14	Panning	0.88
GPP 1	Agitation tank	0.32	GP1	Refining	0.05
GPP 4	Agitation tank	1.42	GP1	Refining	0.11
GPP 4	Agitation tank	2.42	GP1	Refining	0.15
GPP 4	Agitation tank	3.01	GP3	Refining	0.37
GPP 4	Agitation tank	2.89	GP3	Refining	1.81
GPP 8	Agitation tank	0.47	GP3	Refining	1.15
GPP 8	Agitation tank	0.52	GP3	Refining	0.59
GPP 8	Ball mill	0.58	GP4	Refining	0.05
GPP 8	Agitation tank	0.48	GP4	Refining	0.10
GPP 13	Ball mill	0.44	GP4	Refining	0.15
GPP 13	Agitation tank	0.56	GP14	Blow Torching	0.75

Notes: (1) Air velocity is based on the OSHS-DOLE: minimum of 0.25 m/sec.
(2) Values in red imply that the value did not meet the minimum air velocity standard.
(3) Not all of the GPPs were fully operating at the time the research team conducted the measurement; there were no sources of heat because there were no processes being conducted. Thus, not all 16 GPPs were measured for ventilation.

Figure 11. Results of ventilation and oxygen level in UM1



Measuring point		Air velocity (m/sec)	O_2 level (%)
Point A	Entrance of horizontal tunnel	0.28	21.3
Point B	300 metres from the entrance	0.15	21.0
Point C	480 metres from the entrance	0.14	20.5

Measuring point		Air velocity (m/sec)	O_2 level (%)
Point D	Drive (branch) from Point C	0.12	20.5
Point E	640 metres from the entrance	0.10	20.8
Point F	Sinking - about 60 metres deep	0.08	20.5

The provisions of DENR AO No. 97-30 on ventilation prescribe that the quantity of fresh air in UMs, including compressed air, should not be less than $2m^3$/min per man. Fresh air should be supplied underground, in any ventilated district, area or system at any time at which the number of workers employed is at its maximum. Also, the supplied fresh air should contain not less than 20 per cent O_2 and not more than 0.5 per cent CO_2. However, the results of this study show that employers do not conduct the much-needed regular inspections and testing of workplaces to ensure that the ventilation systems in the UMs are adequate.

4.8 Other OSH hazards

Biological hazards. In all workplaces, being exposed to some sort of biological hazard is inevitable. As observed in majority of the GPPs and UMs visited, the workers may be exposed to different biological hazards such as bacteria, viruses, molds, fungi, and so on due to poor housekeeping and sanitation, improper food handling, poor hygiene, improper waste disposal, presence of stagnant water, moist environment and improper ore extraction and handling. Likewise, exposure can also be due to the inadequate and poor condition of the welfare facilities at the sites, particularly to drinking and washing facilities, eating and rest areas and toilets.

The remoteness of the UM sites located in forestlands can also expose miners to insects, plants, animals and other humans with infectious diseases. These sources can cause a variety of health effects, ranging from skin irritation and allergies to viral infections (such as, malaria, tuberculosis, hepatitis, AIDS). In addition, common injuries (for instance, cuts, burns, bruises, punctures, insect and animal bites, and so on) are seldom treated on site because majority of the GPPs and UMs that the research team visited have no first aid stations or personnel capable of providing first aid.

Ergonomic hazards. The nature of work in GPPs and UMs pose a variety of hazards that may lead to ergonomic stresses. Physical demands, such as heavy lifting (ore in sacks), improper way of lifting (loads are placed on heads), overhead works (timberman, electrician, driller), walking in crouch position (underground mining), prolonged standing, prolonged sitting in awkward position, too much bending, use of improvised tools, among others, are some of the ergonomic issues observed during the course of data gathering. However, contrary to what was observed, an average of 9–10 workers interviewed believe that factors related to ergonomics do not affect workers health. Among the ergonomic factors identified, an average of 7–11 and 9–12 workers in UMs and GPPs, respectively, recognize unfit work, heavy workload and improvised tools as ergonomic hazard. On the other hand, only four and five workers recognize that duration of work or the amount of time they spend in UMs and GPPs, respectively, is an ergonomic hazard. Based on the number of workers interviewed in the UMs and GPPs, the workers are not fully aware of the various ergonomic factors that may affect their health (Table 10).

Table 10. Factors affecting workers health

Factors affecting the health of workers	Number of respondents	
	UM	GPP
Workplace policy	1	2
*Heavy load, rain, among others	10	9
*Work unfit to workers	7	10
*Duration of work	4	5
Not good environment	5	8
Dusty workplace	10	5
Dirty/cluttered workplace	7	6
*Improvised tools	11	12

Notes: (1) *Ergonomic factors.
(2) The values are based on multiple responses.

As previously discussed, the GPP and UM workers do not have regular work schedules because the tasks required at the sites are on a per-need basis (based on demand, volume of ore, processing time, and so on). Due to remote location of the UMs, the working hours vary from 4–24 hours, 3–7 days a week. Likewise, the working hours in the GPPs are sometimes extended up to 72 hours whenever the workers have to perform cyanide leaching. Shifting of work schedule is not practiced in both the GPPs and UMs. Such schedules may cause workers to suffer work fatigue, sleep deficit and abnormal sleep patterns.

Psycho-social hazards. Being far away from families for long periods of time, having irregular and insufficient income, and incurring large debts or cash advances from the owners (due to “profit-sharing” and “no gold-no pay” arrangement in SSGM) bother majority of the miners. Whenever the workers witness their co-workers incur fatal and severe injuries, the experience can be traumatic to the other workers and owners/financiers who often feel personally responsible for such injuries.

To cope with the stress and anxiety, the miners resort to smoking and alcohol drinking, which are oftentimes shared with the other workers. During some of the research team’s informal information exchanges with the local residents, the latter shared that some of the miners even use prohibited drugs such as ampethamine, commonly called *shabu* or the poor man’s cocaine. Unlike in SSM, these problems are addressed by LSM companies due to workplace lifestyle and to the establishment of clear drug-related policies.

Safety hazards. Safety has long been a concern in SSM not only in UMs but also in GPPS. Some hazards due to ground instability (stope collapse, cave-in, flooding, loose rocks) and confined conditions (blasting-related accidents, fire) are inherent in underground environments. Table 11 shows the hazards that were observed during the actual data gathering. In both types of work environments, these hazards are associated with the unsafe conditions of the machines, electrical hazards, unstable infrastructures and poor housekeeping, and so on.

Table 11. Safety hazards observed at the time of data gathering

GPPs	UMs
Unguarded belt and pulley of mixing tanks	Exposed and old electrical live wirings
Uncovered mixing/agitation tanks	Intertwining and dangling electrical wirings
Unattended items and equipment	Dilapidated electrical panels
Exposed and old electrical live wirings	No warning signs such as "high voltage"
Dilapidated electrical panels	Narrow pathways
No warning signage such as "high voltage"	Unattended items and equipment
Unstable and dilapidated wooden platform in agitation/leaching area	Improperly stored gas cylinders (LPG)
Poor housekeeping and improper waste disposal	No fire suppression equipment
Dilapidated roofing	Improvised pulleys or *garadad* in local dialect
Work areas without labels for hazardous materials	Improvised or improper choice of working tools
No handrails on staircases	Improvised explosives using ammonium nitrate
Narrow pathways	Poor housekeeping and improper waste disposal
Protruding metal bars	Improvised means of communication may not work
Improperly stored gas cylinders (LPG, acetylene)	Anticipated (inherent) safety hazards
Rusty metal frames that may affect the integrity of the plant	Stope (structure) collapse
Falling hazard from dilapidated roofs	Cave-in
Corroded metal beams and platforms	Flood (water inrushes)
No designated evacuation area	Fire
No written and/or posted emergency procedures	Blasting-related hazards

The identified safety hazards are clear evidence that SSGM companies do not comply with majority of the provisions of AO No. 97-30, particularly the provisions in Chapter IV: Underground Mining Rules, Chapter VII: Emergency Preparedness, and Chapter IX: Electrical and Mechanical Rules (Sections 1 and 2). Likewise, some provisions of the AO No. 97-30 that aims to protect the workers from exposure to health hazards are not adhered to. These provisions include the following:

a. Chapter VI: Health and Sanitation (Sections 1–5);
b. Chapter VIII: Plant Operations (Sections 1 and 4);
c. Chapter XI: Materials Storage and Handling (Sections 1 and 2);
d. Chapter XII: Miscellaneous Safety Rules (Sections 1 and 6).

About 73 per cent and 82 per cent of the UM and GPP workers, respectively, claim that they are provided with PPEs. However, majority of the equipment (namely, face mask and goggles/spectacles) are inappropriate to guard against the type of hazards (dust, cyanide, nitric acid) that miners are exposed to. It is very noticeable that the earplugs to protect the workers from noise exposure are not provided. Table 12 shows employers' poor compliance with the PPE provision for GPP and UM workers.

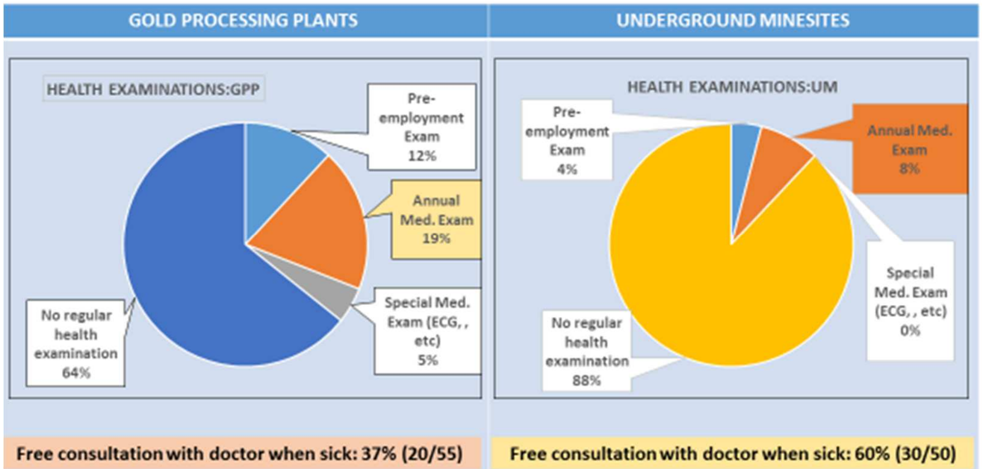
Table 12. PPE provision for GPP and UM workers

Personal protective equipment	GPPs	UMs
PPEs are used at work	73% (40 out of 55)	82% (41 out of 50)
*Gloves	21	15
*Hard hat	13	28
*Boots	26	30
*Face Mask	24	10
*Goggles/Spectacles	4	2
Reflectorized vest	1	2
Earplugs	1	1

Notes: (1) *PPEs
(2) The values are based on multiple responses.

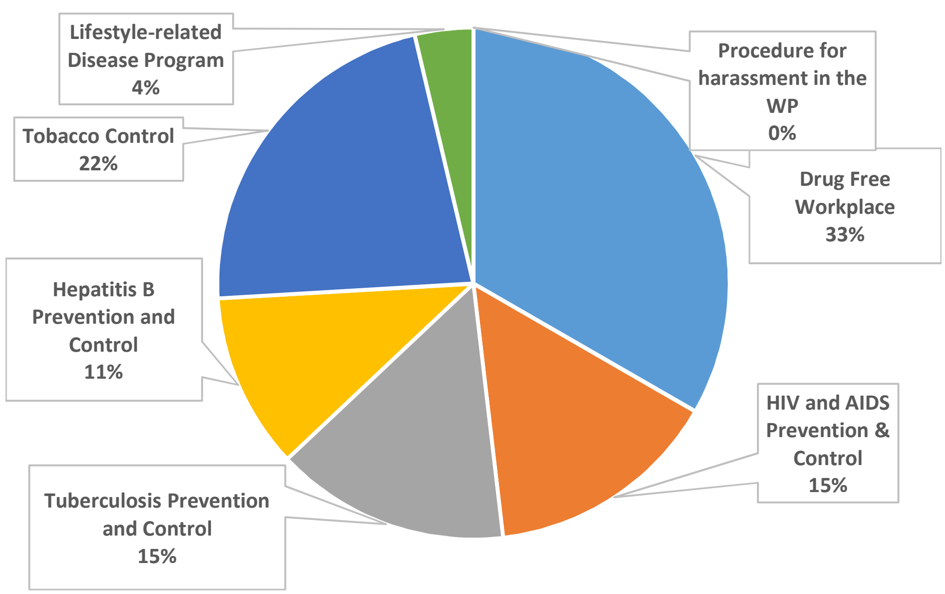
About 12 per cent and 4 per cent of the GPP worker respondents claim that pre-employment and special examinations, respectively, are provided to them. It is remarkable that the said risk-based programmes were noted among the GPPs with permit to operate (Figure 12).

Figure 12. Risk-based programmes: Health programmes



AO 97-30 does not provide for these health programmes in its provisions. Thus, some of the compliances are "voluntary" among the MGB's declared *Minahang Bayan* and respective LGUs. Moreover, according to 22 per cent of the respondents, their employers are implementing a tobacco control programme. The results of the survey also show that workers are not familiar with or unaware of other health programmes, such as lifestyle-related disease control programme and protection against sexual harassment programme. About 4 per cent and 0 per cent response, respectively, were obtained among the GPP respondents (Figure 13).

Figure 13. Special health programmes: GPP



Environmental health hazards from the "closed processing plants". The government can order the closure of a processing plant if it proves to be that the said plant is destroying the surrounding environment and harming the community area where it operates. However, due to the stored bulk mercury contaminated ore tailings that have been exposed to the sun and rains, the hazards emanating from a "closed plant" still remain. They can still pose similar or even greater risks to the environment and to the health of the communities. Moreover, the closed processing plants are not monitored by authorities.

5. CONCLUSIONS

Undoubtedly, SSGM and processing workers are perennially exposed to different types of OSH hazards. Although the government has established a number of laws, regulations, and ordinances to protect workers from OSH hazards, some of the policies that pertain to workers protection do not actually address the workers prevalent needs. There are identifiable gaps in the way SSGM and processing companies provide for the needs of their workers as proven by the exposure of workers, workplace conditions, and work practices vis-a-vis the current SSGM OSH-related laws and policies. The results of this study can attest that the OSH of workers is largely overlooked.

5.1 Absence or insufficient training for SSGM players

LSM companies have good access to various types of safety and health-related trainings, as they have enough resources to implement such activities. The "trainings" in the SSGM subsector, on the other hand, usually depend on the instruction of the team leaders, co-miner's word-of-mouth, and traditions or myths. Accordingly, UM and GPP workplace conditions in SSGM are far from ideal due to the various safety hazards (mechanical, electrical, and so on) that the workers are exposed to. Although these hazards can be easily identified or observed, they are not given attention. Various health hazards (namely, noise, dust and other chemicals, inadequate ventilation and so on) in the GPPs and UMs are present at levels that are detrimental to the workers health. However, majority of the workers perceive them to be otherwise. Incorrect work practices; improper handling/use, storage and disposal of chemicals; and absence of adequate PPE further expose these workers to more hazards. Employers have not conducted actual measurements of hazards or WEM ever since. Likewise, WEM is not provided in AO No. 97-30.

Although AO 97-30 requires employers to provide adequate ventilation in UMs and GPPs and prescribes them to comply with the allowable limits of gases and dusts in the air in UMs, other health hazards (for instance, exposure to noise and hazardous chemicals such as cyanide and nitric acid) are not specified in the Order. In addition, SSGM and processing companies have no risk-based programmes (such as, respiratory protection and hearing conservation programmes) and do not comply with the provisions of AO No. 97-30 on health examination of workers and on welfare facilities. These indicate that their workers health is not a priority.

Indeed, the miners can use their traditional beliefs and myths to indicate that hazards are present. However, their lack of knowledge of these hazards significantly places their lives at risk without even knowing it.

5.2 Unsafe condition of "closed processing plants" may pose environmental health hazards

Overlapping and sometimes conflicting OSH-related policies among concerned national and local governments lead those implementing agencies to interpret the policies differently, which lead to inconsistent policy implementation.

6. RECOMMENDATIONS

6.1 Establish "big brother" and "small brother" (large-scale mines and small-scale mines) partnership to occupational safety and health

The SSM-LSM relationship is often a battle because both types of miners compete for the same resource; likewise, they perceive each other as a threat. However, small-scale miners working together with LSM companies for a healthy and safe environment is actually possible.

LSMs could make it a part of their corporate social responsibility commitment to adopt SSMs and provide them with technical assistance to improve SSMs competencies. This may be done by providing SSMs with monitoring devices and capacity-building programmes that would ensure "healthy and safety" work practices. The LSMs have the technology and technical capacity that can be transferred to SSM groups. By providing mentorship through basic training on the proper usage of tools and machines in underground mining and gold processing, SSMs will have a healthier and safer work environment.

SSMs have limited resources to develop and implement the various programmes that the law mandates. Accordingly, LSMs could extend their health programmes and services to SSMs. Given that they work in the same environment, LSMs could help to ensure that the neighbouring SSMs do not pollute the air and water around them by teaching them the right way of using and disposing chemicals. For example, the mining industry in South Cotobato observes good mining practices and implements OSH and environmental programmes. The local government of the province could then forge partnerships with LSMs such that the LSM OSH trainings and programmes could be transferred to SSM groups.

LSMs could also invite SSM communities to their OSH training or awareness campaigns, including programmes to eliminate child labour and to improve women's conditions through gender and development programmes.

6.2 Implement training needs assessment: OSH training/awareness of all SSM players

Empowering small-scale miners and processing workers by educating them on basic OSH can significantly contribute to the safety and health of workers in SSM and gold processing sites. SSM players from the national and local government, the permittee/owner/financier and the miners and workers in gold processing could be the implementing authorities themselves. Depending on the needs of the UM and GPP workers, the following programmes and trainings can be provided:

a. Basic Occupational Safety and Health (BOSH) training for SSGM and Processing;
b. Hazard identification and control or risk assessment;
c. Work environment measurement;
d. Chemical safety and confined space;
e. Emergency preparedness;
f. Development of health risk-based programmes such as respiratory and hearing conservation programmes;
g. Orientation on OSH provisions in SSM.

In the past, training needs assessments and OSH training/awareness programmes (that is, BOSH) were implemented for LSM companies via the memorandum of agreement among OSHC-DOLE, MGB-DENR and the Chamber of Mines. The same could be done for for SSGM. LGUs could propose partnership with OSHC-DOLE for different SSGM-related trainings.

6.3 Establish a safety and health committee

If feasible, a CSHC could be organized under one umbrella organization, and one unit of this CSHC could be established for each mining province. This initiative could be organized among the LGUs of a certain province or region through the "Joint Safety and Health Committee", which is a forum that brings the internal responsibility system into practice. The committee will be composed of SSM actors (namely, PMRB, LGUs and SSMA) who will perform the duties prescribed in RA No. 7076, Sections 20–21. The CSHC would also have defined functions that would ensure miners' safety and health. The CSHC shall develop standard OSH programmes and policies that would be strictly complied with by the permittee, operator and/or contractor.

The committee may also consist of labour and management representatives who meet on a regular basis to deal with health and safety issues. The advantage of a joint committee is that the in-depth practical knowledge of specific tasks (labour) is brought together with the larger overview of company policies, and procedures (management). Another significant benefit is that the cooperation among all parts of the work force will be enhanced in order to work toward solving health and safety problems. In smaller companies with fewer than a specified number of employees, a health and safety representative is generally required.

6.4 Find the missing link

The government should revisit the DOLE-OSH Standards, DENR AO No. 1997-30, the Safety and Health in Mines Convention, and other policies/issuances related to the OSH in mines, particularly the provisions that will proactively protect the workers from the different OSH. Moreover, the gap on the definition of SSM should be reviewed and updated in accordance with the current conditions and practices of the SSGM. Artisanal mining can be defined based on the current definition of SSM based on AO No. 97-30.
Likewise, the mining industry needs to be re-classified according to small-, medium- and large-scale mining. This could be done based on, but not limited to, the following: technology (tools, machines, processes, and so on), production volume, capitalization and finances, human resource (including number of skilled workers and labour size), size of mine claims, quantity of reserves, operational continuity and reliability, and so on.

Currently, the DOLE OSH Standards do not include the mining industry,[14] as provided in Rule 1003.04: Application to Mines. However, this does not mean that DOLE is not fully involved in ensuring miners' safety and health. As provided in the provisions of DENR AO No. 97-30, Chapter III on the General Provisions, rules 4 and 5, the DENR regional office should furnish the concerned DOLE regional office with monthly reports and statistical data on the incidence of accident and sickness in the mining industry. Likewise, as a member of the multipartite monitoring team in the regions, the Order mandates DOLE to report the results of the agency's accident investigations. Although the provisions of DENR AO No. 97-30 warrant the safety and health of mine workers, the applicable provisions of the Order regarding OSHS must also be considered for a safer and healthier workforce. Provisions regarding the miners safety and health could be included in the amended OSHS and in the revised OSH bill's implementing rules and regulations.

The Safety and Health in Mines Convention provides a complete package of workers protection in both small- and large-scale mines. However, the other provisions that are not applicable to SSM should be addressed immediately. Likewise, provisions

[14]By the time this study was undertaken, the mining industry is not covered by the DOLE OSH-Standards.

specific to processing plant operations need to be incorporated into the existing OSH policies to ensure the safety and health of the workers in processing plants. Furthermore, to avoid confusion, the specific government agency (either DENR or DOLE) responsible for looking after workers protection must be identified. All potential health hazards (physical, chemical, biological and ergonomics) should be identified and included in the standard. The allowable limits or TLVs of gases and chemicals should also be reviewed. Moreover, work environment measurement using monitoring device must be conducted at the workplaces.

Lastly, the pertinent provisions prescribed in the DOLE OSHS, department orders, and issuances, DENR AO No. 1997-30, and applicable mine-related international treaties could be assembled to make it easier for the implementing agencies to execute the provisions and for the permittee/operator/contractor/associations and workers to comply with the regulations.

6.5 Building a culture of safety and health

Behaviour cannot change overnight and rules will not improve by themselves. The government needs to lead in making the small-scale miners look for alternatives other than mercury for gold processing. Little by little, they need to start leaving their old mining practices. If the miners accept and adopt using non-hazardous technology in gold extraction and processing, then this would lead to workers protection, improved working conditions and less environmental degradation. This would then create opportunities for better and sustainable human lives and contribute to environmental protection.

Monitoring of incidents of injuries, accidents, illnesses and diseases among SSM workers should also be strengthened to help the concerned government agencies in analysing the health data of ASGM communities. A good follow-up study could focus on the prevalence silicosis or pneumoconiosis in relation to mining activities.

In terms of formalizing the SSM industry, one of the challenges that should be addressed involves the licenses of SSM. Currently, the government requires almost similar application documents from both SSM and LSM companies, which discourages informal SSM groups to make their operations legal.

LSMs could also be granted with non-expiring permits or operations that usually cover 30 years or more. On the other hand, SSMs need to constantly renew their permits annually — in some instances, less than a year. Considering this, it would be difficult for SSGMs to invest in greener production techniques.

6.6 Control of workers' exposure

The employers of SSM workers should prioritize the protection of their labourers. This could be done through conducting regular monitoring and evaluation of the health hazards present in processing plants and regular monitoring of toxic gases inside the tunnel, particularly after a blasting operation. To do this, the party responsible for conducting such monitoring processes must first be determined.

Likewise, this study recommends using engineering and appropriate personal protective equipment for the workers. In connection to this, the modalities on who should shoulder the cost should be identified. Administrative control measures to limit workers' exposure may not work because of the work arrangements being practiced, particularly in UMs.

The use of toxic/hazardous chemicals should be substituted with non-toxic chemicals. Alternatively, using non-hazardous technology in gold (ore) extraction and processing should be considered. However, the workers may resist this change because of culture and gold recovery issues.

Ultimately, the effective way to deal with OSH problems in SSMs should start with the miners themselves through safe work practices, good housekeeping, use of appropriate PPEs, and provision of welfare facilities among others. Nevertheless, community involvement and family support should not be discounted as important contributor for miners' protection.

6.7 Other recommendations

The following measures could also be done to further improve the condition of the workers in SSGM and processing:

a. Develop risk-based hygiene management plan to address the mine-specific OSH, monitoring programmes and control measures. This plan could also serve as the basis for the development of health policies and programmes aligned to the needs of the SSGM workers.

b. Develop a monitoring system that will strictly evaluate and assess the effectiveness of the mechanisms established to address the issues and concerns of the workers and to ensure the compliance of the operators.

c. Institutionalize the improvements by integrating the policies into the existing mechanisms. Such mechanisms include the annual investment plans and *barangay* development plans of the respective LGUs in those areas where the SSMs operate.

7. WAY FORWARD

This study resulted in a pervasive lore about the government's goal to provide decent work for the population by recognizing and fulfilling its role in providing service that would ensure the safety and health of mine workers in SSGM and processing. It is always said that behaviour cannot change, and policies would not improve on their own. Therefore, it is high time that the government, donor agencies, companies, and workers should work together to develop a unified national policies, regulations, and guidelines that deal specifically with the safety and health of workers in SSGM and gold processing.

Organization leads to formalization. As such, the government needs to prioritize initiatives that would institutionalize the SSGM sector not only for the purpose of formalizing the aspects of land/mineral acquisition, technical, and financial (taxes and sharing), but also for providing solutions to the problems on safety and health of the workers and the community, child labour and environmental degradation, and security in terms of labour arrangements and social benefits.

REFERENCES

911 Metallurgy Corp. 2017. "Gravity borax method mercury free gold recovery", Available at: https://www.911metallurgist.com/blog/mercury-free-gravity-borax-method-gbm [8 Jan. 2018].

Akabzaa, T.; Daramani, A. 2001. *Impact of mining sector investment in Ghana: A study of the Tarkwa mining region*. Unpublished draft report (Penang, Third World Network).

AGC (Artisanal Gold Council). 2019. "Health and artisanal gold mining", Available at: http://www.artisanalgold.org/publications/articles/health-and-artisanal-gold-mining/ [24 Apr. 2019).

American Lung Association. 2018. "Learn about silicosis", 13 March. Available at: https://www.lung.org/lung-health-and-diseases/lung-disease-lookup/silicosis/learn-about-silicosis.html [30 Apr. 2019].

Armah, F.A.; Boamah, S.A.; Quansah, R.; Obiri, S.; Luginaah, I. 2016. "Unsafe occupational health behaviours: Understanding mercury-related environmental health risks to artisanal gold miners in Ghana", in *Frontiers in Environmental Science*, Vol. 4, p. 29.

AFRIM (Alternate Forum for Research in Mindanao). 2012. *A background study on the small-scale gold mining operations in Benguet and South Cotabato and their impact on the economy, the environment and the community*, Bantay Kita Occasional Paper Series No. 2012-02 (Quezon City, Bantay Kita/Action for Economic Reforms).

Artajo, M.I.D. 2012. *Enhancing decent work outcomes in small-scale gold mining.* ILS Discussion Paper Series No. 2012-02 (Manila, Institute for Labor Studies).

Bansah, K.J.; Yalley, A.B.; Dumakor-Dupey, N. 2016. "The hazardous nature of small scale underground mining in Ghana", in *Journal of Sustainable Mining,* Vol. 15, No. 2, pp. 8–25.

Baluda, R.P. 2002. "Small-scale mining in the Baguio mineral district, Philippines", in S. Murao; V.B. Maglambayan; N. dela Cruz (eds): *Small-scale mining in Asia: Observation towards a solution to the issue* (Kent, Mining Journal Books Limited), pp. 11–15.

Basri; Sakakibara, M.; Sera, K. 2017. "Current mercury exposure from artisanal and small-scale gold mining in Bombana, Southeast Sulawesi, Indonesia — Future significant health risks", in *Toxics,* Vol. 5, No. 1, p. 7–17.

Bose-O'Reilley, S.; Steckling, N; Nowak, D. 2016. "P130 health of artisanal and small-scale gold mining", in *Occupational and Environmental Medicine*, Vol. 173, p. A163.

Bugnosen, E. 2001. *Country case study on artisanal and small-scale mining: Philippines*, MMSD Report No. 83 (London, IIED/Geneva, WBCSD).

CDC (Center for Disease Control). 2018. “Heat stress”, 6 June. Available at: https://www.cdc.gov/niosh/topics/heatstress/default.html [2 May 2018].

Cortes-Maramba, N.; Reyes, J.P.; Panganiban, L.C.P.; Francisco-Rivera, A.T.; Suplido, M.L.; and Akagi, H. 2004. “Health and environmental impact of mercury in the Philippines using nuclear techniques”, in *International Nuclear Information System*, Vol. 40, No. 15, pp. 75–90.

DENR (Department of Environment and Natural Resources). 2018. “Minamata Convention”, 6 June. Available at: http://intl.denr.gov.ph/index.php/database-un-conventions/article/8 [16 Apr. 2019].

DENR AO No. 97-30 (Department of Environment and Natural Resources Administrative Order No. 30, series of 1997). Small-scale mine safety rules and regulations (11 Sept. 1997).

DENR AO No. 2015-03. Revised implementing rules and regulations of Republic Act No. 7076, Otherwise known as the “People’s Small-Scale Mining Act of 1991” (16 Mar. 2015).

DOLE (Department of Labor and Employment). 2015. “Post investigation report: Investigation on the possible violation of labour laws in the illegal mining sites/structures in Camarines Norte.”

Eller, P.M.; Casinelli, M.E. eds. 1994. *NIOSH manual of analytical methods*. 4th edition. (Darby, PA, Diane Publishing Co.).

Esdaile, L.J.; Chalker, J.M. 2018. “The mercury problem in artisanal and small-scale gold mining”, in *Chemistry–A European Journal*, Vol. 24, No. 27, pp. 6905–6916.

EPA (United States Environmental Protection Agency). 2018. “Reducing mercury pollution from artisanal and small-scale gold mining”, 21 Nov. Available at: https://www.epa.gov/international-cooperation/reducing-mercury-pollution-artisanal-and-small-scale-gold-mining [8 Jan 2018].

-—. 2019. “Minamata Convention on Mercury”, 11 Mar. Available at: https://www.epa.gov/international-cooperation/minamata-convention-mercury [16 Apr. 2019].

Fraser Institute. 2012. “What is artisanal and small-scale mining?” Available at: http://www.miningfacts.org/communities/what-is-artisanal-and-small-scale-mining/ [19 Jan. 2018].

Haq, A.; Achmadi, U.F.; Mallongi, A. 2018. “Environmental health risk assessment due to exposure in artisanal and small-scale gold mining area of Lebak district”, in *Global Journal of Health Science*, Vol. 10, No. 3, pp. 125–131.

Harari, R.; Harari, F.F. 2013. “Safety and health in mining in Ecuador”, in K. Elgstrand; E. Vingard (eds): *Occupational safety and health in mining: Anthology on the situation in 16 mining countries* (Gothenburg, University of Gothenburg), pp. 171–178.

Hendrick, D.J.; Sizer, K.E. 1992. “’Breathing’ coal mines and surface asphyxiation from stythe (black damp)”, in *British Medical Journal*, Vol. 305, No. 6852, pp. 509–510.

Hentschel, T.; Hruschka, F.; Priester, M. 2002. *Global report on artisanal and small-scale mining*, MMSD Report No. 70 (London, IIED/Geneva, WBCSD).

Hidayati, N; Juhaeti, T.; Syarif, F. 2009. “Mercury and cyanide contaminations in gold mine environment and possible solution of cleaning up by using phytoextraction”, in *HAYATI Journal of Biosciences,* Vol. 16, No. 3, pp. 88–94.

Hilson, G. 2002. “Small-scale mining and its socio-economic impact in developing countries”, in *Natural Resources Forum*, Vol. 26, No. 1, pp. 3–13.

Health and Safety Executive. 2017. “Noise at work – FAQs,” 25 Sept. Available at: http://www.hse.gov.uk/noise/faq.htm [23 Apr. 2019].

ILO (International Labour Organization). 2019. “Convening Actors to Develop and Implement Strategies to Reduce Child Labour and Improve Working Conditions in Artisanal and Small-Scale Gold Mining (CARING GOLD MINING PROJECT)”, Available at: https://www.ilo.org/manila/projects/WCMS_517531/lang--en/index.htm [17 Apr. 2019].

Kaniteng, L.N. 2004. *Small-scale mining in the Philippines: The forgotten partner,* paper presented at the International Symposium on the Diversity of Mining and Sustainable Local Development: A Meeting to Study the Business Practices of Small-Scale Gold Mining in Benguet, Philippines, University of the Philippines, Baguio City, 17 Mar.

Kusena, W.; Zhou, T. 2014. “Occupational hazards, injuries and illnesses associated with small-scale gold mining: A case of Ward 19, Zvishavane, Zimbabwe”, in The Dyke, Vol. 8, No. 1, pp. 41–57.

Labonne, B. 1996. “Artisanal mining: An economic stepping stone for women”, in *Natural Resources Forum,* Vol. 20, No. 2, pp. 117–122.

Lanticse, L.J.; Clemente, E.; Mendoza, H. 2002. “Chemical separation of mercury from amalgamation effluent”, in S. Murao; V.B. Maglambayan; N. dela Cruz (eds): *Small-scale mining in Asia: Observation towards a solution to the issue* (Kent, Mining Journal Books Limited), pp. 27–30.

Leung, A.M.R.; Lu, J.L.DP. 2016. “Environmental health and safety hazards of indigenous small-scale gold mining using cyanidation in the Philippines”, in *Environmental Health Insights,* Vol. 10, pp. 125–135.

Lu, J.L.D.P. 2012. “Occupational health and safety in small scale mining: Focus on women workers in the Philippines”, in *Journal of International Women's Studies*, Vol. 13, No. 3, pp. 103–113.

Long, R.N.; Sun, K.; Netizel, R.L. 2015. “Injury risk factors in a small-scale gold mining community in Ghana’s Upper East Region”, International Journal of Environmental Research and Public Health, Vol. 12, No. 8, pp. 8744–8761.

-—. 2015. “Investigations of safety conditions in small-scale industries in the Philippines”, in *Environmental Science: An Indian Journal,* Vol. 10, No. 11, pp. 423–428.

Maglambayan, V.B.; Murao, S. 2002. “Problems of small-scale mining around Baguio City, Philippines”, in S. Murao; V.B. Maglambayan; N. dela Cruz (eds): *Small-scale mining in Asia: Observation towards a solution to the issue* (Kent, Mining Journal Books Limited), pp. 3–7.

MGB (Mines and Geosciences Bureau). 2017. *Mining facts and figures.* Quezon City: MGB, Available at: http://www.mgb.gov.ph/images/homepage-images/mining-facts-and-figures-------updated-January-2017.pdf [18 May 2017].

Mine Engineer. 2012. “Mercury amalgamation”, Available at: http://mine-engineer.com/mining/minproc/MercAmal.htm [29 Apr. 2019].

NEDA (National Economic Development Authority). 2016. “About Ambisyon Natin 2040”, Available at: http://2040.neda.gov.ph/about-ambisyon-natin-2040/ [23 Apr. 2019].

NIOSH (National Institute for Occupational Safety and Health). 2002. *Health effects of occupational exposure to respirable crystalline silica* (Washington, DC).

NOAA (US National Oceanic and Atmospheric Administration). 2019. “WetBulb globe temperature”, Available at: https://www.weather.gov/tsa/wbgt [1 May 2019].

O’Connell, R. et al. *GFMS gold survey 2018* (London, Thomson Reuters).

Opare, J.K.L. et al. 2010. "Outbreak of cholera in the East Akim municipality of Ghana following unhygienic practices by small-scale gold miners", in *Ghana Medical Journal*, Vol. 46, No. 3, pp. 116–123.

OSHA (Occupational Safety and Health Administration). 2017. "Section III: Chapter 4 – Heat stress", 15 Sep. Available at: https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html [2 May 2019].

OSHC (Occupational Safety and Health Council). 2003. *Biological hazards–Prevention and personal protection* (Hong Kong, OSHC).

Parsons, K. 2010. "Chapter 5: Thermal comfort in buildings", in M. Hall (ed): *Materials for energy efficiency and thermal comfort in buildings* (Cambridge, Woodhead Publishing), pp. 127–147.

PD No. 1899 (Presidential Decree No. 1899). Establishing small-scale mining as a new dimension in mineral development (23 Jan. 1984).

Ralph, O.; Gilles, N.; Fon, N.; Luma, H.; Greg, N. 2018. "Impact of artisanal gold mining on human health and the environment in the Batouri Gold District, East Cameroon", in *Academic Journal of Interdisciplinary Studies*, Vol. 7, No. 1, pp. 25–44.

Rappler. 2012. "Fast facts: Mining in the Philippines", 7 Sep. Available at: http://www.rappler.com/business/special-report/whymining/11983-fast-facts-mining-philippines [18 May 2017].

Republic Act No. 7076 (RA No. 7076). Am Act creating a people's small-scale mining programme and for other purposes (27 June 1991).

Reade, M.C.; Davies, S.R.; Morely, P.T.; Dennet, J.; Jacobs, I.C. 2012. "Management of cyanide poisoning", in *Emergency Medicine Australasia*, Vol. 24, pp. 225–238.

Rey, E.M.; Saturay, R.M., Jr. 2005. *Small-scale mining in the Philippines: Towards genuine national development.* (Quezon City, Agham – Advocates of Science and Technology for the People), unpublished.

Safe Work Australia. 2010. National hazard exposure worker surveillance: Vibration exposure and the provision of vibration control measures in Australian workplaces (Canberra).

Timko, R.J.; Derick, L.R. 1995. *Predicting spontaneous heating in coal mine pillars*, paper presented at the 7th US Mine Ventilation Symposium. Lexington, Kentucky, 5–7 June.

Torres, E.B.; Gapas, J.L.; Greaves, I.A; Ong, T.T. 2002. "Occupational health in the Philippines", in *Occupational Medicine*, Vol. 17, No. 3, pp. 455–468.

Tse, L.A.; Li, Z.M.; Wong, T.W.; Fu, Z.M.; Yu, I.T. 2007. "High prevalence of accelerated silicosis among gold miners in Jiangxi, China", in *American Journal of Industrial Medicine*, Vol. 50, No. 12, pp. 876–880.

Triple i Consulting. 2019. "Environmental compliance certificate," 28 Jan. Available at: https://www.tripleiconsulting.com/environmental-compliance-certificate/ [23 Apr. 2019].

Tujan, A., Jr.; Guzman, R.B. 2002. *Globalizing Philippine mining.* 2nd ed. (Manila, Ibon Foundation, Inc.).

UNECA (United Nations Economic Commission for Africa). 2002. *Compendium on best practices in small-scale mining in Africa* (Ababa).

Verbrugge, B.; Besmanos, B.; Buxton, A. 2014. *Artisanal and small-scale mining: Protecting those 'doing the dirty work',* IIED Briefing Papers (London, IIED).

Verbrugge, B. 2015. "The economic logic of persistent informality: Artisanal and small-scale mining in the southern Philippines", in *Development and Change*, Vol. 46, No. 5, pp. 1023–1046.

WHO (World Health Organization). 2011. *Occupational health programme of WHO headquarters* (Geneva, WHO).

-—. 2016. *Environmental and occupational health hazards associated with artisanal and small-scale gold mining*, WHO Technical Paper Series No. 1 (Geneva).

WorkSafe Mahi Haomaru Aotearoa. 2017. "Ventilation in underground mines and tunnels", 7 Sep. Available at: https://worksafe.govt.nz/topic-and-industry/extractives/mining/ventilation-in-underground-mines-and-tunnels/ [8 Jan. 2018].