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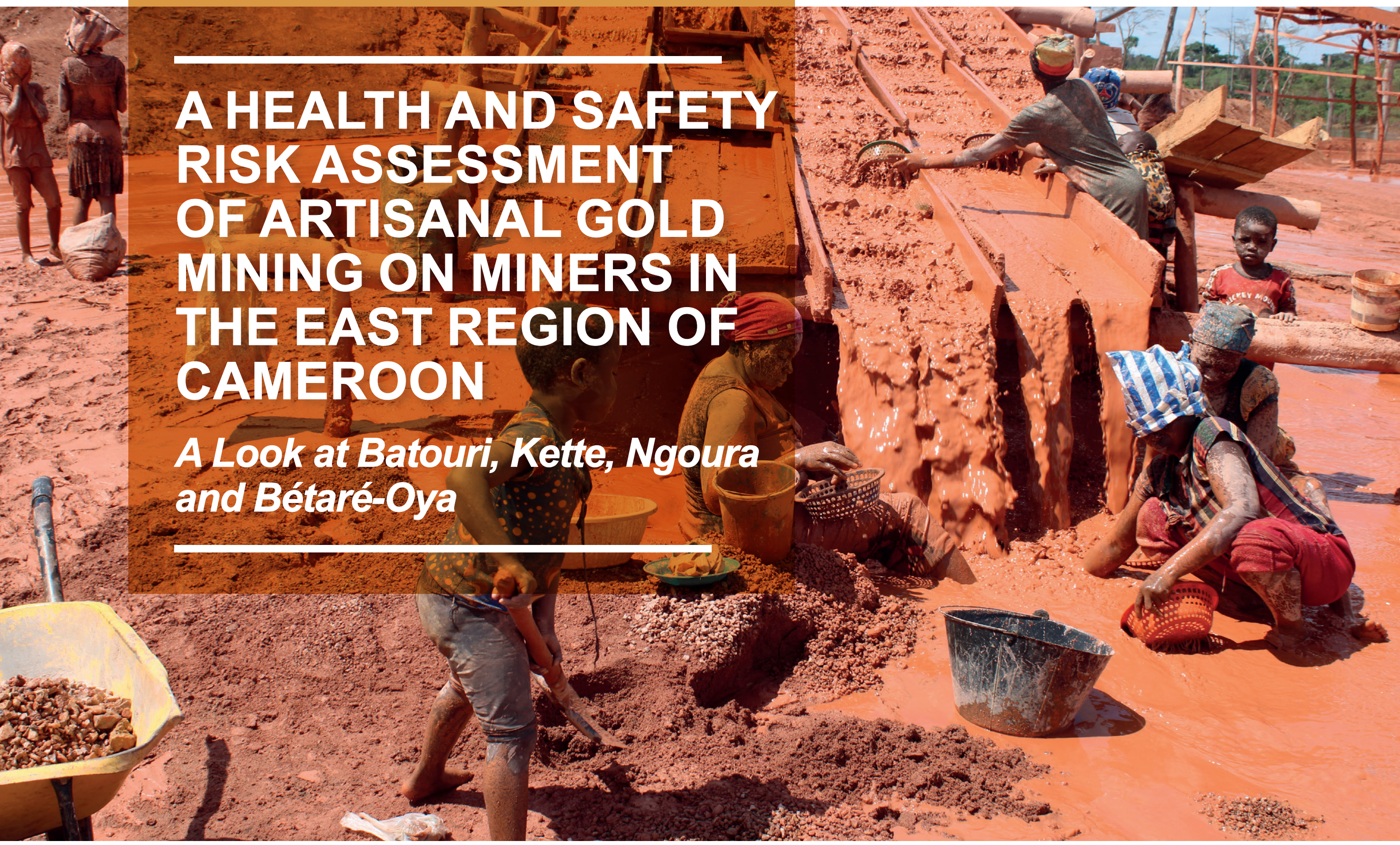

A HEALTH AND SAFETY RISK ASSESSMENT OF ARTISANAL GOLD MINING ON MINERS IN THE EAST REGION OF CAMEROON

A Look at Batouri, Kette, Ngoura and Bétaré-Oya

WORKING DOCUMENT N°002

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PREFACE

On global basis, ASM is the single largest intentional-release of mercury in the world. It is responsible for 37% of mercury emissions, one that results in severe exposure to workers though inhalation of vaporized mercury, releases to the environment and poses risks to those in the nearby community who eat fish contaminated with mercury. Women of child-bearing age and children are most vulnerable (UNEP, 2008:2).

3 to 9 fatal accidents every year as a result of mining in Cameroon, and a high frequency of non-fatal work accidents, but the nature and magnitude of the injuries was not clearly reported (Obase et al 2018). They suggested that fatalities were grossly underreported due to lack of a proper reporting system

In Cameroon, FODER has reported 205 deaths in artisanal gold mining sites in the East and Adamawa Regions 2014 and 2022, these accidents are mostly due to landslides as a result of absence of minimum individual and collective safety rules, and the presence of numerous non-rehabilitated mining sites, which have been transformed into artificial lakes.

Little or no research has been conducted in Cameroon to assess miners' knowledge regarding workplace H&S and so not much is known about their awareness of the H&S hazards in mining, and the measures employed to control their risks and improve H&S at work.

In the face of this situation, it is therefore important to assess the health and safety risks of artisanal miners so as to propose realistic preventive measures. This study is carried out as part of the Mines, Environment, and Health & Society Phase 2 Project (ProMESS 2) funded by the EU.

ACKNOWLEDGEMENT

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It is also an opportunity to thank Prof SAMA Dohbit offered a selfless assistance to the acquisition of an ethical approval, The Coordinator of FODER, Mr. KAMGA Justin Christophe and We equally acknowledge all field facilitators, Junior MANDOUKE, Thomas ZAORO, and Phillipe DONO and all artisan miners whose active participation was so contributory to the realization of the field work.

EXECUTIVE SUMMARY

Background: Artisanal and small-scale mining (ASM) in Cameroon is principally concentrated in the east region of Cameroon and though it serves as a considerable source of revenue to the local population though its repercussions on the health and safety of miners and their families cannot be overemphasized.

Objectives: The aim of this study was to evaluate the health and safety risks to which artisanal gold miners in the East Region of Cameroon are exposed to.

Methodology: A quantitative, cross-sectional descriptive survey design was used involving 134 miners from four mining subdivisions and questionnaires were used to collect relevant data. OHS risk assessment was conducted through direct inspection of 16 different workplaces and sixty scalp hair samples were collected and analyzed for total mercury concentration by spectrophotometry via a Milestone DMA-80 Direct Mercury Analyzer.

Results: Generally, there was a deficit in the implementation of the legal requirements overseeing the mining sector. The most hazardous workplaces were the excavation workplaces where the risk of landslides, collapse of galleries, entrapment in tunnels, rockfalls, falls, and drowning in abandoned waterlogged pits were elicited and ranged from high to extreme requiring senior management or immediate action. The most common health problems among miners were malaria (59.5%), musculoskeletal pains (50.4%), hernias (7.6%), dermatitis (7.6%), diarrheal conditions (6.1%), visual problems (6.1%) and others (18.3%) like headaches and fatigue. The incidence proportion of work accidents within one year was 38.5% and the estimated incidence rate was 26.5. Wounds and lacerations, sprains and strains, and contusions constituted the most frequently occurring injuries, and lack of PPE, lack of skills and expertise, and bad equipment were causative factors. The maximum, minimum and mean hair mercury levels were 8.97 mg/kg, 0.78 mg/kg and 2.1±1.8 mg/kg respectively, and the total hair mercury concentration was above the WHO internationally recommended level in 71.1% of the subjects. There was a significant positive correlation between mercury levels with frequency of exposure to mercury, and the number of working days per week. Most cases of deaths occurred in underground tunnels (53.3%) and open pits (36.7%) usually as a result of collapse of galleries, landslides, falls, and drowning in abandoned waterlogged pits.

Conclusion: Work accidents, injuries, fatalities and ill health are an important concern in artisanal gold mining and an incorporation of fundamental OHS principles would contribute tremendously in mitigating these hazards.

Key words / Concepts: Health & safety, Risk, artisanal gold mining, East-Cameroon.

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LIST OF ABBREVIATIONS

AGM:	Artisanal Gold Mining
ASGM:	Artisanal and Small Scale Gold Mining
ASM:	Artisanal and Small-scale Mining
FODER:	Forêts et Développement Rural
Hg:	Mercury
H&S:	Health and Safety
ILO:	International Labor Organization
IRL:	Internationally Recommended Level
NOHSC:	National Occupational Health & Safety Commission
OHS/OSH:	Occupational Health and Safety
PPE:	Personal Protective Equipment
STI:	Sexually Transmitted Infection
UN:	United Nations
UNEP:	United Nations Environment Program
WHO:	World Health Organization

Introduction

Artisanal and small-scale mining (ASM) refers to mining operations by individuals, groups, families or cooperatives with minimal or no mechanization, often in the informal (illegal) sector of the market (Hentschel et al 2003:5). It is recognized as a considerable source of revenue for millions of people worldwide (World Gold Council 2017). The number of people relying on ASM for livelihood might have reached 40.5 million in 2017, working in more than 80 countries around the world, and producing some 12 – 15% of the world's mined gold (IGF 2017:2-3; UNEP 2013:12-13; World Bank 2013:5). In Africa there are about 9 million ASM operators, and about 54 million people whose livelihood depend on the sector (IGF 2017:5).

In Cameroon, ASM is mostly concentrated in the East Region. The sector accounts for less than 0.1% of the country's GDP but is one of the key pillars of the Government's Vision 2035 to attain emergent country status (EITI 2019:1; The World Bank 2017:1). The total number of people involved in ASM in Cameroon is not known but approximately 40,000 artisan miners are estimated to operate (IGF 2017:79). It is the main source of family income in mining communities, and it helps to slow down rural exodus and promotes the development of several related business activities.

Despite its social and economic importance, it contributes significantly to the degradation of the health of gold miners and their families. According to WHO (2016:5), many of the health and safety problems in small-scale mining may be linked to the absence of regulation in the ASM sector; lack of miner education about health hazards; limited access to protective equipment and limited technical knowledge due to lack of access to technical training, and low literacy rates. The artisanal miners, women and children involved in mining are highly exposed to health, environmental and safety risks at workplaces. ASM is generating a workplace fatality rate of up to 90 times higher than mines in indulstrialized countries (ILO 1999:1-3). While it is impossible to say howmany deaths and accidents occur in small-scale mines, due to under-reporting and the clandestine nature of much of the work, the risks of total and disabling accidents are high particulary in underground mines (ILO 1999:2-3). In Cameroon, FODER has reported 205 deaths in artisanal gold mining (ASGM) sites in the East and Adamawa Regions 2014 and 2022. These accidents are mostly due to landslides as a result of absence of minimum individual and collective safety rules, and the presence of numerous non-rehabilitated mining sites, which have been transformed into artificial lakes.

Also mercury, a known hazardous substance, is used in the process of gold mining to capture gold from the ore. On global basis, ASM is the single largest intentional-release of mercury in the world. It is responsible for 37% of mercury emissions, one that results in severe exposure to workers though inhalation of vaporized mercury, releases to the environment and poses risks to those in the nearby community who eat fish contaminated with mercury. Women of child-bearing age and children are most vulnerable (UNEP, 2008:2). The main health outcomes include neurological disorders, kidney dysfunction, and immunotoxicity (WHO, 2013).

In the face of this situation, it is therefore important to assess the health and safety risks of artisanal miners so as to propose realistic preventive measures. This study is carried out as part of the Mines, Environment, Health & Society Phase 2 Project (ProMESS 2) funded by the EU.

1.1 goals and objectives

This study has as goal to increase the public's awareness on the health and safety risks to which artisanal gold miners in the East Region of Cameroon are exposed to.

The specific objectives are to:

- Evaluate the health and safety risks associated with AGM in the east region of Cameroon.
- Analyze the causes of illnesses and work accidents related to AGM in the east region of Cameroon.
- Evaluate the degree of exposure of artisanal miners to mercury and the repercussions on health in the east region of Cameroon.
- Propose realistic and achievable preventive and corrective measures to mitigate health and safety hazards in artisanal gold mining in the east region of Cameroon.

1.2 Methodology

a. 1.2.1 Study design, setting and sampling

A quantitative, cross-sectional descriptive survey design was used involving four mining districts in the East region: Batouri, Kette, Ngoura and Bétaré-Oya **(figure 1).** Mining is the major economic activity in these districts besides other subsistence activities like agriculture. The activity is primarily informal in nature; however, it is coordinated by the Cameroon National Mining Corporation (SONAMINES). Access within the mining sites is by tracks and forest roads and the activity is principally carried out by natives with the use of rudimentary tools. The target population included all the artisan miners who had been practicing AGM activities for a minimum of one year at the time of study, and who consented to participate. A nonprobability purposive method of sampling was used.

b. 1.2.2 Data collection

The study was approved by the Ministry of Public Health, and an ethical approval was obtained from the Institutional Review Board of the Faculty of Medicine and Biomedical Sciences of the University of Yaoundé 1.

In each of the mining districts, community sensitization was done by field facilitators in the pre-data collection phase. Data collection began with mass recruitment of study participants with the help of field facilitators, gatekeepers and local authorities. The aim of study was explained to the participants, health talks on hazards in mining and dangers of mercury were offered, and consents to participate were then obtained from the participants **(figure 1)**. Questionnaires were then administered by trained data collectors, to collect sociodemographic characteristics of miners, organizational arrangements for OHS management, planning and implementation, and performance evaluation as shown in the annexure. Hair samples of varying lengths (0.5 – 1 cm) and quantities (50 – 100 strands), were collected as close as possible to the scalp, labeled in pieces of tin foil, stored in transparent plastic bags containing desiccants, and transported to the Analytical Chemistry Laboratory of the University of Michigan USA for mercury analysis.

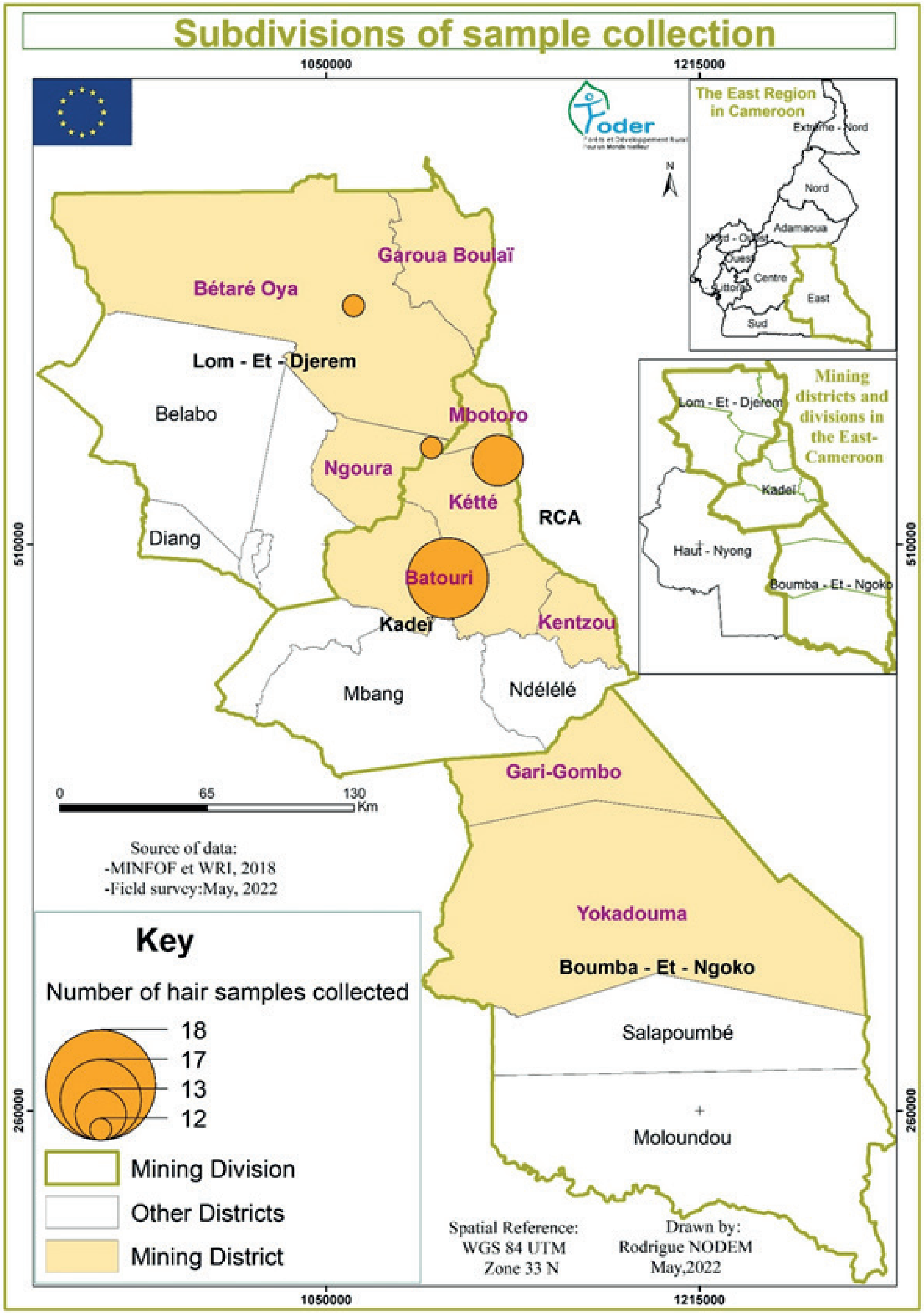

Figure 1: Map of study location showing sample sites

Identification and documentation of health and safety hazards at workplaces was then achieved through visits with the use of a workplace inspection checklist. Elements in the checklist included general conditions of the workplaces, supervision of work, use of personal protective equipment (PPE), hygiene and sanitation, nature and maintenance of work equipment, and health and safety relating to various mining process **(annexure 2).**

Figure 2. Data collection: (a) health talk,

Figure 2. Data collection: (b) hair sample collection, (c) administration of questionnaires.

c.1.2.3 Sample analysis

The hair samples were analyzed via a Milestone DMA-80 Direct Mercury Analyzer calibrated with linear, low range (0 – 20 ng) calibration curve using known standard reference materials. The instrument thermally decomposes the sample, amalgamates the mercury, and uses spectrophotometry to quantify the concentration of Total Mercury in each sample. Samples were weighed into cuvettes prior to analysis and ranged from 0.5 – 10 mg depending on density of hair. Cuvettes were loaded into the sample tray and taken into the instrument individually for analysis. Blanks were run along with the samples.

d. Health and safety risk analysis

This was done with the use of a Risk Analysis Form **(annexure 4)**. Risk is the likelihood that exposure to a hazard will lead to an injury or health problem, and how serious it could be (Bern et al 2010:4). In relation to each hazard identified, it was identified what could happen, how it could happen, why it could happen, persons at risks, mode of exposure to the hazards and existing control measures. Finally, the "likelihood of exposure" and the "consequence of exposure" to each hazard identified were assessed. A quantitative approach to risk assessment was then employed using the formula:

Risk = [Likelihood] [Consequence].

Risk was rated as either "Extreme Risk", requiring immediate action, "High Risk", requiring senior management attention, "Moderate Risk," need for reduction to as low as reasonably practicable, and "Low Risk," which is tolerable and managed by routine procedures.

e. Data analysis

Information from the questionnaire was recoded, cleaned and saved in a personal PC and protected with a password. Analysis was done using the IBM Statistical Package for the Social Science (SPSS) version 20. Means were compared using analysis of variance.

The Pearson Chi-square test was used to test the relationship between variables, and p-value $P<0.05$ at 95% confidence interval (CI) was considered statistically significant. Bivariate analysis was used to determine the strength of association between total mercury (THg) concentration of hair, and age and duration of mining. The data was presented on charts and tables, and major themes emerging from the workplace inspection were presented accordingly.

AN OVERVIEW OF THE ARTISA-NAL GOLD MINING PROCESS

2.1 The mining process

The ASGM process was basically the same in all the four districts visited and gold capture with the use of mercury (amalgamation method) was common.

The mining process generally comprises the following steps:

a. 2.1.1 Extraction

Miners exploit alluvial deposits or hard rock-deposits with the use of rudimentary tools such as pickaxes, spades, crowbars, shovels, pans and water pumps. Two types of pits are created – open pits with depths reaching 5 – 7 m **(figure 3A)**, and underground mines (tunnels) with lengths reaching up to 12 m **(figure 3B)**. Sediment or overburden is removed and the ore is mined by surface excavation or by tunnelling. Mining through tunneling and undercutting of pit wall edges is also done in some abandoned pits already created by excavators from local semi-mechanized companies.

b. 2.1.2 Processing

In this step, the gold is liberated from other minerals. The gold particles in alluvial deposits are often already separated and require little mechanical treatment. While for hard rock deposits, crushing and milling are required **(figures 3C and 3D)**. Primary crushing is done manually with the use of hammers and heavy metal rods. Mills are then used to grind the ore into smaller particles and, eventually, fine powder.

c.2.1.3 Concentration

At this stage, gold is further separated from other materials through gravity concentration based on its relatively higher density. The alluvial ore or the ground-up ore from mills are flushed into a sluice box running down over a carpet in a chute **(figure 3E)**. The heavy minerals (washed products) collected from the carpet are then concentrated with use of aluminum basins in a process known as panning.

d. 2.1.4 Amalgamation

Mercury is used in gold mining because of its ability to bind to gold forming a mercury-gold alloy called an "amalgam", which helps separate the precious metal from rock, sand and other material. There are two main methods of amalgamation used in ASGM: whole-ore amalgamation and concentrate amalgamation. Concentrate amalgamation was the method observed in all the four districts studied. In concentrate amalgamation, the mercury is added only to the smaller quantity of material (concentrate) that results from the concentration step **(figure 3F)**. As a result, considerably less mercury is generally used.

Whereas in whole-ore amalgamation, mercury is added with little prior commination and concentration. As such, large quantities of mercury are often used and most is released as waste into the mine tailings. Human exposure to mercury at this stage may occur either directly through physical contact, or indirectly (oral route) through the consumption of dietary products from ecosystem into which it is released.

e. Burning of amalgam

The amalgam is then heated, often in a shovel or metal pan over an open fire, to vaporize the mercury, leaving behind only the gold. In "open burning", all of the mercury vapor is emitted into the air, and human exposure to mercury at this stage is through direct inhalation. This was the method of gold refining observed in all the four districts.

Throughout these work process miners as well as others living and working nearby to ASGM processing sites are exposed to a variety of environmental and occupational health and safety risks that will be discussed in the later sections.

Figure 3. Different steps in the artisanal gold mining process: Open pits (A); entrance into a tunnel (B);

Figure 3. Different steps in the artisanal gold mining process: crushing of hard rock (C); grinding (D);

Figure 3. Different steps in the artisanal gold mining process: Sluicing (E); amalgamating (F).

2.2 Sociodemographic characteristics of artisan miners

The demographics of artisanal gold miners vary considerably, and all ages can be represented. In this study evidence was retrieved from 134 artisanal gold miners recruited from four major artisanal gold mining districts namely Batouri (36), Kette (32), Ngoura (28) and Bétaré-Oya (38) as shown in figure 4 below. Majority of them (95.5%) were literate with at least a primary school level of education. The workforce was generated by both men and woman of all ages, with a male predominance of 122 (91%). Majority were adults between the ages of 20 – 39 years constituting 71.6% of the study population, with a mean age of 29.1±9.0 years. There were 20 (14.9%) workers of the middle age group (40 – 59 years), and no elderly (≥60 years) encountered at the time of study. We also observed 2 (1.5%) children (≤14 years) and 14 (10.5%) teenagers during the study period.

Concerning categorization of job, majority of the artisan miners 118 (88.1%) worked as employees, involved in the various tasks of the mining process (digging, crushing, milling, washing, sluicing, panning, amalgamating with mercury, burning of amalgam, and mineral collection), while 16 (11.9%) were mine site owners, principally in charge of recruiting workers. In some cases, it could be a family-based subsistence activity involving all members of the household. Even though there was no strict division of labor as many workers were involved in more than one tasks, men principally worked in mines, while women and children around mines and at home, balancing mining and household responsibilities. Their mean work experience was 9.8±10.1 years, and they worked on average 5.6±1.2 days a week and 9.4±4.2 hours per day.

ASGM wasn't the principal occupation to a majority of these workers (58.2%), who reported other activities like subsistence farming, trading, motor bike transportation, and fishing etc. Their average monthly income estimated as a function of the quantity of gold produced per month was around 343,411 FCFA. Even though this is higher than the estimated monthly cost of a basic but decent standard of living for a typical family in rural Cameroon, most of these artisanal gold miners were characterized as poor, living in local settlements and in very dilapidated conditions **(figure 5)**.

Table 2. Sociodemographic characteristics of artisanal gold miners

Miners' characteristics	Batouri n (%)	Kette n (%)	Ngoura n (%)	Bétaré-Oya n (%)	Total N (%)
Number of respondents	36 (26.9)	32 (23.9)	28 (20.9)	38 (28.4)	134 (100)
Sex					
Male	26 (72.2)	32 (100)	28 (100)	36 (94.7)	122 (91.0)
Females	10 (27.8)	0	0	2 (5.3)	12 (9.0)
Age (mean±SD)a	30.3±10.8	31.7±12.1	28.8±9.2	26.0±5.7	29.1±9.8
Marital status					
Married	18 (50.0)	16 (53.3)	20 (76.9)	22 (57.9)	76 (58.5)
Not married	18 (50.0)	14 (46.7)	6 (23.1)	16 (42.1)	54 (41.5)
Literacy level					
No schooling	4 (11.1)	0	0	2 (5.3)	6 (4.5)
At least primary education	32 (88.9)	32 (100)	26 (100)	36 (94.7)	126 (95.5)
Number of workers per the mining sites (mean±SD)b	17.9±26.9	41.9±67.4	5.8±3.0	11.1±5.5	18.5±35.3
Job category					
Miner	26 (72.2)	32 (100)	26 (92.9)	34 (89.5)	118 (88.1)
Owner	10 (27.8)	0	2 (7.1)	4 (10.5)	16 (11.9)
Work experience (years) (mean±SD)c	11.6±12.8	13.5±12.2	10.1±6.7	4.6±3.6	9.8±10.1
Number of working days per week (mean±SD)	6.1±0.9	5.6±1.5	5.3±1.0	5.5±1.1	5.6±1.2
Working hours per day (mean±SD)	11.3±4.3	9.3±4.3	8.4±4.6	8.5±3.2	9.4±4.2
Mining as principal occupation?					
Yes	12 (33.3)	10 (31.3)	12 (42.9)	22 (57.9)	56 (41.8)
No	24 (66.7)	22 (68.8)	16 (57.1)	16 (42.1)	78 (58.2)
Estimated average monthly income (FCFA)d	376,000	290,700	333,471	369,352	343,411
ap=0.085, bp=0.03, cp=0.001, dp=0.826					

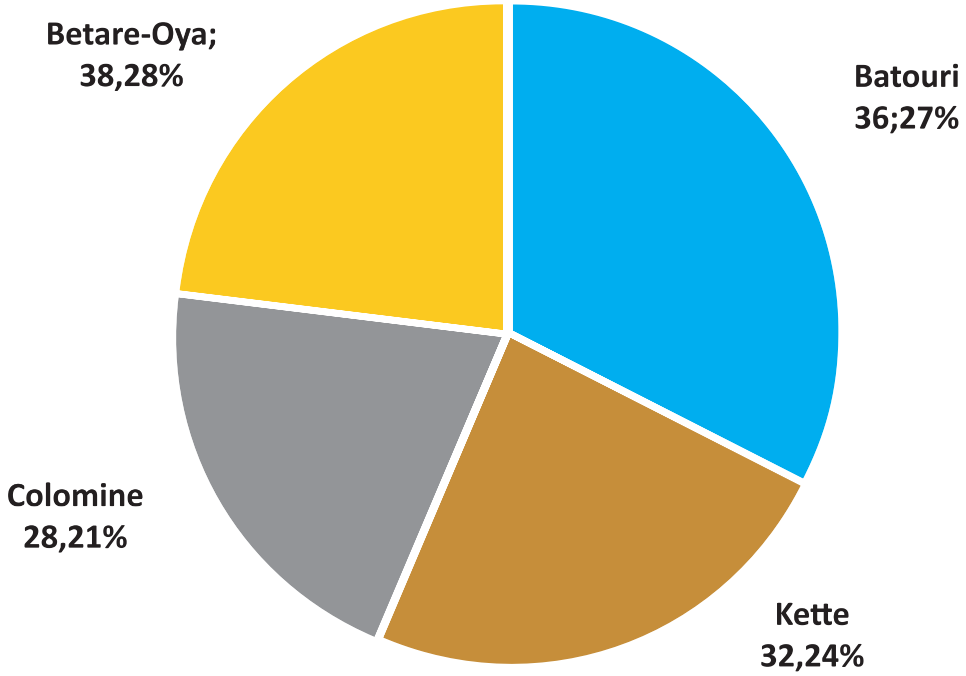

Figure 4. Population distribution of study participants

Figure 5. *An artisanal gold mining settlement in Bétaré-Oya with typical housing structures of artisanal gold miners.*

HEALTH AND SAFETY RISKS ASSOCIATED WITH ARTISANAL GOLD MINING

3.1 General conditions of OHS standards

Generally, there is a lack of clarity and implementation of the law overseeing the legal operations in the artisanal gold mining across all the four districts visited, which was related to the lack of awareness of the existence of such policies. Majority of the artisan miners (70.9%) have never heard about occupational health and safety, and were unaware (59.7%) of the existence of the national OHS regulations which governs all workplaces in Cameroon. Most of the workplaces (71.2%) did not have a health and safety policy, even though a good organizational workplace culture was observed in some sites like the Kpawea in Kette. In some others (23.9%), the implementation of hygiene, safety and accident prevention measures was solely the responsibility of workers themselves rather than the employer. On the other hand, most workers (93.1%) did not know it was their duties and responsibilities to report accidents, fatalities, alleged dangers or unsafe conditions. Also, labor force was generally unskilled and a significant proportion of workers (88.1%) had never benefited from any OHS training or induction. In Batouri and Ngoura, none of the workers had ever received training in H&S, while at least some few workers in Kette and Bétaré-Oya had been trained (table 3).

Concerning hazards in mining most workers (81.3%) were aware of at least one hazard. The practice of supply and use of PPE was generally poor as only 48.5% of workers reported to have at least used PPE. These PPEs included coveralls, helmets, gloves and footwears. However, when a comparison was done across the four districts, Bétaré-Oya was the only district where this practice was good as only a very small proportion of workers (10.5%) had never used PPEs.

Table 3. General conditions of the occupational health and safety standards

Variable	Batouri n (%)	Kette n (%)	Ngoura n (%)	Bétaré-Oya n (%)	Total N (%)
LEGAL REQUIREMENTS, AND HEALTH AND SAFETY POLICY					
Have you ever heard of OHS?					
Yes	7 (19.4)	12 (37.5)	6 (21.4)	14 (36.8)	39 (29.1)
No	29 (80.6)	20 (62.5)	22 (78.6)	24 (63.2)	95 (70.9)
Awareness of existence of national OHS laws or regulations					
Yes	8 (22.2)	16 (50.0)	6 (21.4)	24 (63.2)	54 (40.3)
No	28 (77.8)	16 (50.0)	22 (78.6)	14 (36.8)	80 (59.7)
Do you people have a health and safety policy specific for this workplace?					
Yes	4 (11.8)	16 (50.0)	2 (7.1)	12 (31.6)	34 (25.8)
No	28 (82.4)	16 (50.0)	26 (92.9)	24 (63.2)	94 (71.2)
Don’t know	2 (5.9)	0	0	2 (5.3)	4 (3.0)
RIGHTS AND DUTIES OF EMPLOYERS AND EMPLOYEES					
Who is responsible for H&S in this workplace?					
The employer (owner)	14 (38.9)	18 (56.3)	8 (28.6)	36 (94.7)	76 (56.7)
Workers themselves	10 (27.8)	8 (25.0)	14 (50.0)	0	32 (23.9)
No body	12 (33.3)	6 (18.8)	6 (21.4)	2 (5.3)	26 (19.4)
Employees’ duty and responsibility awareness in maintaining H&S					
Yes	16 (44.4)	20 (62.5)	10 (41.7)	28 (77.8)	74 (57.8)
No	20 (55.6)	12 (37.5)	14 (58.3)	8 (22.2)	54 (42.2)
COMPETENCE AND TRAINING					
Have you ever benefited from any training in H&S?					
Yes	0	6 (18.8)	0	10 (26.3)	16 (11.9)
No	36 (100)	26 (81.3)	28 (100)	28 (73.7)	118 (88.1)

AWARENESS OF HAZARDS AND RISKS					
Are you aware of certain things or conditions called hazards that can cause injury or illness to you? a p = 0.01					
Yes	28 (87.5)	32 (100.0)	14 (53.8)	30 (78.9)	104 (81.3)
No	4 (12.5)	0	12 (46.2)	8 (21.1)	24 (18.8)
Do you use PPE during work?					
Yes always	2 (5.9)	2 (6.3)	4 (14.3)	20 (52.6)	28 (21.2)
Yes, some times	6 (17.6)	14 (43.8)	2 (7.1)	14 (36.8)	36 (27.3)
Never used	26 (76.5)	16 (50.0)	22 (78.6)	4 (10.5)	68 (51.5)

3.2 Health and safety risk assessment

A hazard is a physical situation with a potential for human injury or damage to environment, or some combination of these (Alli 2008:124). Two main categories are health hazards (that can cause an occupational illness), and safety hazards (that can cause an occupational injury). A risk describes the probability (chance or likelihood) that a hazard will cause harm and how serious the damage, injury or illness could be if happens (Bern et al 2010:34).

A total of 16 different workplaces were inspected and categorized into six (6): surface mines, underground tunnels, crushers, grinders, concentrators, and amalgam burners **(table 4)**.

In surface mines, miners were exposed to the risk of falls due to existence of abandoned pits and untidy paths and ramps, risk of drowning due to existence of waterlogged pits, risk of landslides due to unstable pit walls and undercutting of pit walls, and the risk of rock falls due to piling of overburden at pit wall edges, all which could lead to major physical injuries or deaths.

In underground mining most tunnels lacked adequate supports and alternative exits which was associated with the risk of entrapment. Also, the uncontrolled digging of tunnels observed in some abandoned semi-mechanized pits, and working in tunnels during rainy seasons generally were associated with the risk of collapse of galleries, which could result in major injuries or deaths. We also observed some poorly ventilated tunnels, but no cases of suffocation had ever been reported and the risk was rated as moderate. Very few hazards were identified in the crushing, grinding, and ore-concentration workplaces. Open burning of amalgam was observed in all four districts and this was associated with the risk of mercury toxicity through inhalation.

High priority risks with major and catastrophic consequences included falls, drowning, landslides, rockfalls, entrapment, collapse of galleries and mercury toxicity and requiring immediate actions or senior management attention **(table 4).**

Table 4. *Hazards and risks in selected artisanal and small-scale gold mining sites in east* ***region of Cameroon.***

Workplace	Hazard	Possible risk	Likelihood level	Consequence	Risk rating
Surface mines	Existence of abandoned pits	Falls into pits	Possible	Moderate	High
	Existence of waterlogged pits	Drowning	Possible	Moderate	High
	Undercutting of pit walls	Landslides	Possible	Moderate	High
	Piling of overburden at pit wall edges	Rockfalls	Likely	Minor	Moderate
	Untidy paths and ramps	Falls into pit	Likely	Minor	Moderate
	Unstable pit walls	Landslides	Possible	Major	Extreme
Underground mining	Lack of adequate supports of adits and tunnels	Entrapment	Possible	Major	Extreme
	Tunneling in abandoned semi-mechanized pits	Collapse of gallery	Possible	Major	Extreme
	Working in tunnel during rainy seasons	Collapse of gallery	Possible	Major	Extreme
	Lack of alternative exits for adits	Entrapment	Unlikely	Major	High
	Poor ventilation of tunnels	Suffocation	Rare	Moderate	Moderate
Crushing workplace	Repeated limb motion	Repetitive stress injuries	Possible	Insignificant	Low
	Inappropriate technique	Digital injuries	Possible	Insignificant	Low
Grinding workplace	Exposure to dust	Respiratory problems	Possible	Minor	Moderate
Concentration units	Mercury handling	Contact dermatitis and other skin conditions	Rare	Minor	Low
Amalgam burning workplace	Open burning of mercury amalgam	Mercury toxicity	Unlikely	Major	High

CAUSES OF ILLNESSES, WORK ACCIDENTS AND DEATHS

4.1 Causes of illness

AGM has significant impact on many aspects of health and well-being. The mean work experience of the miners was 9.8±10.1 years and 79.1% of them reported to have at least fallen sick following induction of mining activities. The following health problems were reported in order of prevalence: malaria (59.5%), musculoskeletal pains (50.4%), hernias (7.6%), dermatitis (7.6%), diarrheal conditions (6.1%), visual problems (6.1%) and others (18.3%) like headaches and fatigue. Most of these health problems could be explained by the different hazards inherent in the mining activities **(table 5 & figure 6).**

Table 5. *Causes of illnesses among artisanal gold miners*

Variable	Batouri n (%)	Kette n (%)	Ngoura n (%)	Bétaré-Oya n (%)	Total N (%)
Have you ever fallen sick since you started working?					
Yes	26 (72.2)	30 (93.8)	20 (71.4)	30 (78.9)	106 (79.1)
No	10 (27.8)	2 (6.3)	8 (28.6)	8 (21.1)	28 (20.9)
How often do you fall sick?					
Almost everyday	4 (13.3)	4 (12.5)	0	0	8 (6.3)
At least every week	4 (13.3)	4 (12.5)	8 (28.6)	8 (22.2)	24 (19.0)
At least every month	6 (20.0)	12 (37.5)	6 (21.4)	12 (33.3)	36 (28.6)
At least every year	2 (6.7)	8 (25.0)	4 (14.3)	10 (27.8)	24 (19.0)
Rarely	14 (46.7)	4 (12.5)	10 (35.7)	6 (16.7)	34 (27.0)
Which of the following health problem do you usually suffer from? (n=131, missing values = 3)					
Malaria	26 (33.3)	24 (30.8)	16 (20.5)	12 (15.4)	78 (59.5)
Diarrheal conditions	2 (25.0)	4 (50.0)	2 (25.0)	0	8 (6.1)

Respiratory conditions	2 (50.0)	0	0	2 (50.0)	4 (3.1)
Hernia	2 (20.0)	6 (60.0)	0	2 (20.0)	10 (7.6)
Musculoskeletal pains	14 (21.2)	20 (30.3)	10 (15.2)	22 (33.3)	66 (50.4)
Skin conditions	2 (20.0)	4 (40.0)	0	4 (40.0)	10 (7.6)
Visual problems	4 (50.0)	0	0	4 (50.0)	8 (6.1)
Others (headaches, fatigue, gastritis)	6 (25.0)	2 (8.3)	6 (25.0)	10 (41.7)	24 (18.3)
Do you sleep under a treated mosquito bed net?					
Yes	14 (38.9)	24 (75.0)	26 (92.9)	18 (50.0)	82 (62.1)
No	22 (61.1)	8 (25.0)	2 (7.1)	18 (50.0)	50 (37.9)

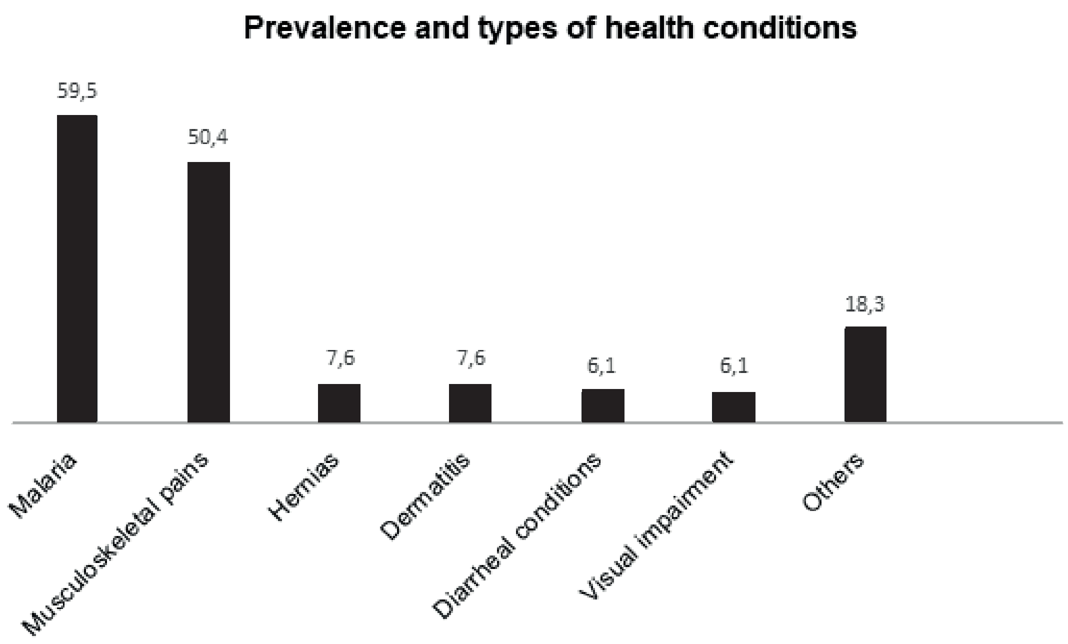

Figure 6. Illnesses in artisanal gold mining

For example, the high prevalence of malaria could be explained by the fact that majority of these miners live in settlements characterized by the existence of bushes in their environments which harbor mosquitoes. Also, the existence of abandoned waterlogged pits in the vicinity of households act as major breeding sites for mosquitoes, which are vectors for the malaria parasite. Even though the use of mosquito bed nets was reported by a majority (62.1%) as a preventive measure, there is need for its reinforcement and other measures of prophylaxis.

Also, the musculoskeletal pains, fatigue and hernias reported in this study may be explained by the strenuous nature of the activities involved in ore extraction and transportation, and the long duration of working hours. Most miners extract ore manually with the use of rudimentary equipment, and transport it on their heads with the use of bags, and sometimes wheelbarrows.

Moreso, the presence of diarrheal conditions could be explained by the lack proper hygiene and sanitation in most mining sites. Majority of the sites inspected lacked toilets or latrines and miners defecate in nearby bushes during working hours. Also, most workplaces lacked adequate supply of portable water, and in some circumstances drinking of the mine water was observed. Finally, the respiratory conditions like cough reported in this study could be explained by the inhalation of dust as a result of pollution from the grinding mills.

We have similar results with Wiliams et al (2016) in Ghana, who also reported malaria (36.8%) as the most common disease among artisan gold miners, among other conditions such skin diseases (29.1%), respiratory diseases (18.8%), diarrheal conditions (13.7%), vision problems (5.1%), and body pains (2.6%).

4.2 Causes of work accidents and deaths

Work accidents and fatalities were also reported among the four districts visited as shown in **table 6** below.

Within the past 1 year, 48 of the 134 individuals interviewed experienced at least an episode of work accident, giving the calculated incidence proportion of 38.5%. Of these accidents, 18 occurred in Bétaré-Oya, 14 Batouri, 12 in Kette, and 4 in Ngoura. With an average of 6 working days a week, and 9 hours of work per day, we estimated that within one year, 134 miners would have worked on average 361,800 hours, giving an incidence rate of 26.5. The section of workplace with the highest prevalence of work accidents was the underground tunnels (42.9%), followed by the open pit diggers (28.6%).

The types of accidents reported included getting injured by working tool (33.3%), falls (23.8%), landslides (14.3%), contact with chemical substance (9.5%), entrapment (4.8%), crushed injury (4.8%), drowning (4.8%) and others (4.8%) (figure 7). The most prevalent types of injuries were wounds and lacerations (43.5%), sprains and strains (39.1%) and contusions (8.7%), and most of these injuries involved the upper and lower limbs. According to most of the participants, the possible causes of most of these injuries were lack of PPE (60.9%), lack of skills and expertise (16.7%), and bad equipment (8.7%) (figure 8). According to some miners, there are about 2.64±3.8 deaths recorded every year as a result of some of these accidents, majority of which occurred in underground tunnels (53.3%) and open pits (36.7%), and in most cases the deaths occurred as a result of collapse of galleries, landslides, falls, and drowning in waterlogged pits (figure 9).

Table 6. Causes of work accidents and fatalities in artisanal gold mines.

Variable	Batouri n (%)	Kette n (%)	Ngoura n (%)	Bétaré-Oya n (%)	Total N (%)
When was the last time you sustained an accident?					
Days ago	0	2 (6.3)	0	2 (5.3)	**4 (3.0)**
Weeks ago	2 (5.6)	0	0	6 (15.8)	**8 (6.0)**
Some months ago	8 (22.2)	4 (12.5)	2 (7.1)	2 (5.3)	**16 (11.9)**
At least one year ago	4 (11.1)	6 (18.8)	2 (7.1)	8 (21.1)	**20 (14.9)**
Never	22 (61.1)	20 (62.5)	24 (85.7)	20 (52.6)	**86 (64.2)**
In which section of the workplace did the accident occur?					
Diggers (open pit)	0	2 (16.7)	2 (50.0)	8 (57.1)	**12 (28.6)**
Diggers (underground)	6 (50.0)	8 (66.7)	2 (50.0)	2 (14.3)	**18 (42.9)**
Crushers	0	0	0	4 (28.6)	**4 (9.5)**
Grinders	0	2 (16.7)	0	0	**2 (4.8)**
Washing (sluicing)	2 (16.7)	0	0	0	**2 (4.8)**
Washing (panning)	4 (33.3)	0	0	0	**4 (9.5)**
What type of accident was it?					
Falls	0	2 (16.7)	0	8 (66.7)	**10 (23.8)**
Landslides	2 (14.3)	0	4 (100.0)	0	**6 (14.3)**
Entrapment	2 (14.3)	0	0	0	**2 (4.8)**
Crushed injury	0	0	0	2 (16.7)	**2 (4.8)**
Injured by working tool	4 (28.6)	8 (66.7)	0	2 (16.7)	**14 (33.3)**
Drowning	0	2 (16.7)	0	0	**2 (4.8)**
Contact with chemical substance	4 (28.6)	0	0	0	**4 (9.5)**
Others	2 (14.3)	0	0	0	**2 (4.8)**
What kind of injury did you sustain?					
Contusion	0	0	2 (50.0)	2 (8.712.5)	**4 (8.7)**
Sprain and strain	6 (42.9)	4 (33.3)	0	8 (50.0)	**18 (39.1)**

Wounds & lacerations	6 (42.9)	8 (66.7)	2 (50.0)	4 (25.0)	**20 (43.5)**
Burns	2 (14.3)	0	0	0	**2 (4.3)**
Others	0	0	0	2 (12.5)	**2 (4.3)**
Which part of your body was injured?					
Head & neck	2 (14.3)	2 (16.7)	0	0	**4 (8.7)**
Chest	0	0	0	2 (12.5)	**2 (4.3)**
Abdomen	0	0	0	2 (12.5)	**2 (4.3)**
Perineum	0	2 (16.7)	0	0	**2 (4.3)**
Upper limbs	6 (42.9)	4 (33.3)	2 (50.0)	6 (37.5)	**18 (39.1)**
Lower limbs	6 (42.9)	4 (33.3)	2 (50.0)	6 (37.5)	**18 (39.1)**
What was the possible cause of the injury?					
Lack of PPE	8 (57.1)	8 (66.7)	2 (50.0)	10 (62.5)	**28 (60.9)**
Bad equipment	0	0	2 (50.0)	2 (12.5)	**4 (8.7)**
Lack of skills and expertise	2 (14.3)	4 (33.3)	0	2 (12.5)	**8 (16.7)**
Tiredness and fatigue	2 (14.3)	0	0	0	**2 (4.3)**
Unsafe working environment	0	0	0	2 (12.5)	**2 (4.3)**
Others	2 (14.3)	0	0	0	**2 (4.3)**
Has there been any deaths as a result of accident for the past one year?					
Yes	22 (61.1)	20 (66.7)	4 (14.3)	14 (36.8)	**60 (45.50**
No	12 (33.3)	10 (33.3)	18 (64.3)	18 (47.4)	**58 (43.9)**
Don’t know	2 (5.6)	0	6 (21.4)	6 (15.80	**14 (10.6)**
Number of deaths for the pas one year	5.4±6.3	2±1.0	1	1	**2.64±3.8**
In which section of the mine was it recorded?					
Digging (open pit)	2 (10.0)	10 (45.5)	0	10 (71.4)	**22 (36.7)**
Digging (underground)	16 (80.0)	12 (54.5)	0	4 (28.6)	**32 (53.3)**
Crushing	2 (10.0)	0	0	0	**2 (3.3)**
Washing (sluicing)	0	0	4 (100.0)	0	**4 (6.7)**
What was the nature of the accident?					
Falls	2 (11.1)	0	0	0	**2 (3.7)**
Landslides	4 (22.2)	0	0	6 (42.9)	**10 (18.5)**
Collapse of galleries	12 (66.7)	10 (55.6)	0	8 (57.1)	**30 (55.6)**
Drowning	0	8 (44.4)	4 (100.0)	0	**12 (22.2)**

We have similar results with Benedict et al (2015) still in Ghana, who reported an overall incidence proportion of 23.5%. Even though they reported a relatively low overall injury rate 5.39 per 100 person years, similar results (25.31 per 100 person years) were observed when compared in the subgroup of miners with less than one year of working experience. Also, the most injury-prone mining activities in their study were excavation (58.7%) and crushing (23.1%) and majority of the injuries were lacerations involving the upper or lower limbs. Still in Ghana, Kyeremateng-Amoah and Edith (2015) reported that according to hospital records collapse of mine pits and falls constituted the most frequent cause of accidents.

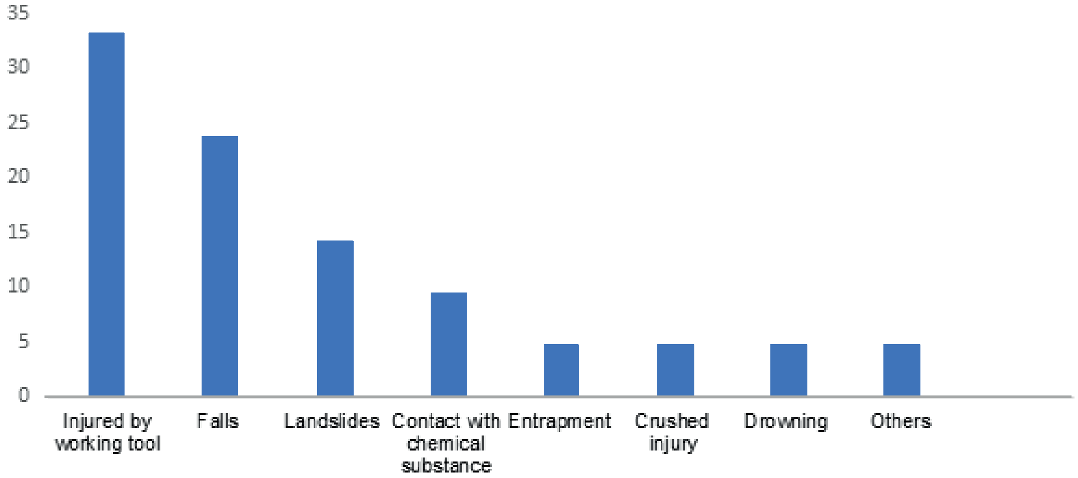

Figure 7. *Prevalence and types of work accidents in artisanal gold mines East Cameroon*

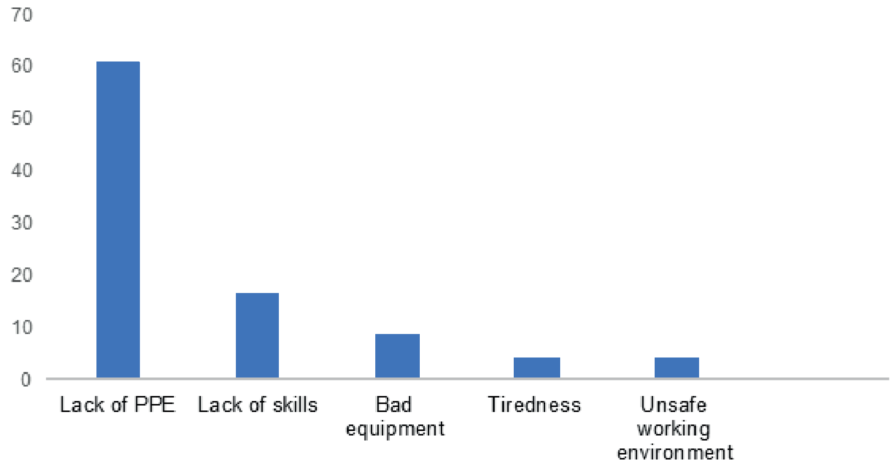

Figure 8*. Causes of work injuries among artisanal gold miners in the east region of Cameroon.*

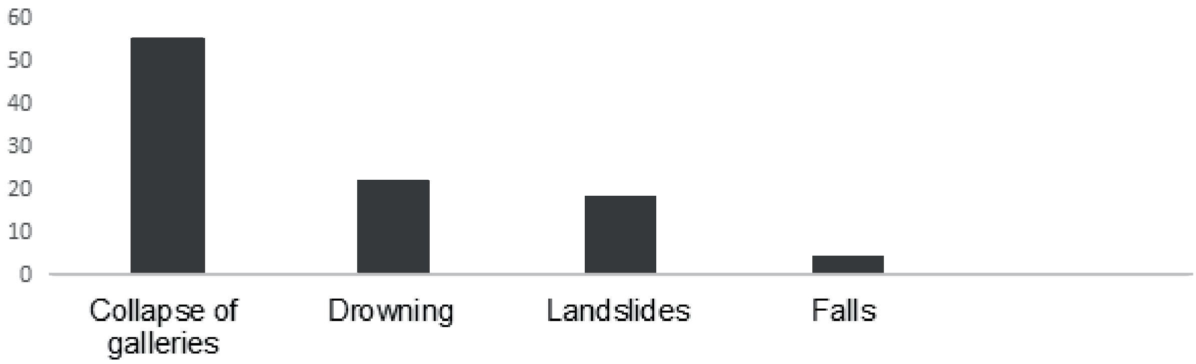

Figure 9. *Causes of fatalities in AGM in the east region of Cameroon*

MERCURY EXPOSURE LEVELS AND HEALTH IMPACTS IN ARTISANAL GOLD MINING IN EAST CAMEROON

The focus of health impact of exposure to mercury in this study was more on chronic, low or moderate exposure, not high concentration exposure by methylmercury, as was the case in Minamata disease in the past. Because more than one organ may be involved, the clinical features may vary invariably.

5.1 General characteristics of mercury

Mercury occurs in several forms including metallic (elemental), inorganic, and organic compounds. This study focused on the health effects of elemental mercury used in the AGM process to form gold amalgam. The most important route of exposure is through inhalation from amalgam burning, even though exposure can also occur through physical contact (skin and mucous membranes) through direct manipulation of mercury. Metallic mercury is then absorbed in varying rates through the respiratory tract and skin and mucous membranes into the systemic circulation where it builds up in various tissues (mainly brain and kidney), including the hair (Byeong-Jin et al., 2016:2). Elemental mercury intoxication manifests in neurological, kidney and autoimmune impairment (WHO 2016:7). The half-life of mercury in the body is about 70 days (Byeong-Jin et al., 2016). The migration of mercury to hair is irreversible and therefore hair mercury concentration is used as a biomarker for chronic exposure or intoxication to mercury. According to WHO, the internationally recommended limit (IRL) of hair mercury concentration is 1 mg/kg, even though mercury concentration generally does not exceed 10 mg/kg.

5.2 Hair mercury levels

In this study 60 hair samples were drawn from miners from the four districts as follows: Batouri (18), Kette (17), Ngoura (12) and Bétaré-Oya (13). Most of them were amalgam burners and collectors of gold. Fifty-two of them were males (86.7%) while 8 (13.3%) were females. Exposure to elemental mercury was through inhalation and physical contact, and the frequency of exposure varied from daily (37.5%), weekly (57.1%) and monthly (5.4%) exposures **(Table 7).**

Table 7. *Characteristics of subjects from which hair sampling was done*

Variable	Batouri n (%)	Kette n (%)	Ngoura n (%)	Bétaré-Oya n (%)	Total N (%)
Number of samples	18 (23.4)	17 (17.9)	12 (23.6)	13 (35.1)	60 (100)
Sex					
Male	13 (72.2)	16 (94.1)	11 (91.7)	12 (92.3)	52 (86.7)
Female	5 (27.8)	1 (5.9)	1 (8.3)	1 (7.7)	8 (13.3)
Mean age	30.8±8.7	36.18±12.5	28.8±10.3	24.0±9.1	30.5±10.9
Marital status					
Married	10 (55.6)	13 (81.3)	9 (75.0)	6 (46.2)	38 (64.4)
Not married	8 (44.4)	3 (18.8)	3 (25.0)	7 (53.8)	21 (35.6)
Highest level of education					
No schooling	4 (22.2)	2 (11.8)	0	1 (7.7)	7 (11.7)
Primary	7 (38.9)	7 (41.2)	5 (41.7)	5 (38.5)	24 (40.0)
Secondary	7 (38.9)	8 (47.1)	7 (58.3)	7 (53.8)	29 (48.3)
Role					
Amalgam burners	13 (72.2)	12 (70.6)	11 (91.7)	11 (84.6)	47 (78.3)
Collectors	5 (27.8)	5 (29.4)	1 (8.3)	2 (15.4)	13 (21.7)
Duration of mining (years)	10.2±9.6	16.8±14.0	13.4±10.3	4.3±1.7	11.6±11.0
Number working days a week	6.3±0.8	5.4±1.3	5.8±1.3	5.8±1.6	5.9±1.3
Number of working hours a day	9.6±2.4	7.9±2.3	7.5±3.8	8.9±2.8	8.6±2.8
Frequency of exposure					
Daily	7 (46.7)	5 (29.4)	4 (33.3)	5 (41.7)	21 (37.5)
Weekly	7 (46.7)	10 (58.8)	8 (66.7)	7 (58.3)	32 (57.1)
Monthly	1 (6.7)	2 (11.8)	0	0	3 (5.4)

Mercury was undetectable in 5 (8.3%) samples. It was within the WHO IRL in 12 (20.0%) samples, and it was above the WHO IRL in 43 (71.7%) of the samples. The highest, lowest, and mean levels of total hair mercury were 8.97 mg/kg, 0.78 mg/kg and 2.1±1.8 mg/kg respectively **(table 8)**. High levels were generally observed in Bétaré-oya, and was more prevalent among men than women. According to risk assessment the exposure to mercury by amalgam burners was rated as high. There is therefore risk of chronic toxicity especially in long term if not controlled.

Table 8. *Hair mercury levels among miners in the east region of Cameroon.*

Total mercury levels (mg/kg)	Batouri n (%)	Kette n (%)	Ngoura n (%)	Bétaré-oya n (%)	Total N (%)
Non detected	3 (16.7)	1 (5.9)	1 (8.3)	0	5 (8.3)
Within WHO IRL (≤ 1)	4 (22.2)	5 (29.4)	1 (8.3)	2 (15.4)	12 (20.0)
Elevated (1.01 – 10)	11 (61.1)	11 (64.7)	10 (83.3)	11 (84.6)	43 (71.7)
Mean *	1.6±1.2	1.3±0.8	2.5±1.4	3.4±3.0	2.1±1.8
Minimum	0	0	0	0.79	0
Maximum	3.62	3.56	4.63	8.97	8.97
Range	3.62	3.56	4.63	8.18	8.97
*p = 0.01					

An overview on mercury concentration levels in samples collected is shown in the table 9 below:

Table 9: Onverview on hair mercury in each samples

Sample ID	Total Mercury (mg/kg)
BAH01	2.65
BAH02	1.66
BAH03	0.54
BAH04	0.56
BAH05	ND
BAH06	2.17
BAH07	ND
BAH08	1.37
BAH09	2.69
BAH10	3.62
BAH11	0.42

BAH12	2.82
BAH13	1.96
BAH14	3.23
BAH15	0.95
BAH16	3.21
BAH17	1.55
BAH18	ND
KEH01	1.02
KEH02	1.1
KEH03	0.45
KEH04	0.93
KEH05	1.92
KEH06	0.88
KEH07	0.66
KEH08	2.05
KEH09	0.42
KEH10	3.56
KEH11	1.07
KEH12	1.68
KEH13	1.68
KEH14	ND
KEH15	1.52
KEH16	1.88
KEH17	1.63
COH01	2.63
COH02	3.57
COH03	0.85
COH04	4.63
COH05	2.87
COH06	1.08
COH07	ND
COH08	3.27

COH09	3.69
COH10	2.22
COH11	3.35
COH12	1.43
BOH01	1.55
BOH02	8.97
BOH03	0.79
BOH04	1.78
BOH05	2.75
BOH06	8.34
BOH07	0.94
BOH08	2.24
BOH09	1.12
BOH10	2.13
BOH11	2.42
BOH12	2.81
BOH13	8.16

5.3 Relationship between hair mercury levels and miners' characteristics

We found a positive correlation between total hair mercury concentrations with the frequency of exposure ($p = 0.04$), and the number of working days per week ($p = 0.03$). Increased number of working days (up to 7 days) and the high frequencies of manipulation of elemental mercury (daily) were associated with increased exposures, and thus increased mercury hair concentrations **(table 9)**. On the other hand, there was a negative correlation between age and the mercury hair concentrations. Generally total mercury hair concentrations were lower in the elderly when compared to the younger population ($p = 0.12$). This may be as a result of decreased cellular transport of mercury due to decreased cell function which occurs with aging. A comparison with other studies shows similar results (table 10). A comparison of the results with other studies in Senegal and Ghana shows similar results as shown in

Table 10. *Spearman's rho correlation between mercury levels and some miners' characteristics*

Miners' characteristics	Correlation coefficient	P-value
Frequency of exposure to mercury	0.28	0.04
Number of working days per week	0.28	0.03
Age	-0.20	0.12

Table 11*. Comparison of result of THg hair levels with other studies*

Total hair Hg (mg/kg)	This study Cameroon 2022	Senegal (Birane et al., 2014)	Ghana (Opoku et al, 2019)	Indonesia (Harianja et al., 2020)
Sample size (N)	60	111	68	71
Maximum	8.97	7.67	15.97	18
Mean	2.1	1.1	6.59	3.21

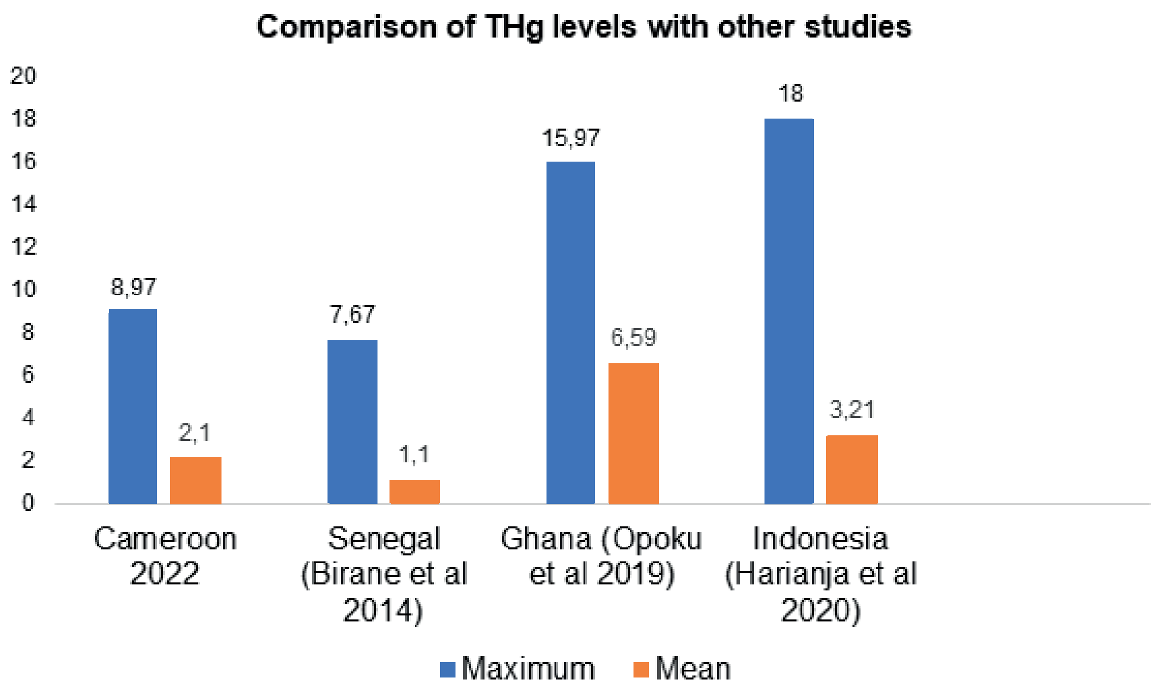

Figure 10. *Comparison of total hair mercury levels among artisan miners in Cameroon with those from other countries*

5.4 Health impact of mercury toxicity

Ten symptoms possibly related to chronic exposure of mercury were explored as shown in the table 12 below. The most prevalent symptoms were unusual tiredness 35 (58.3) and headaches 33 (55%) even though other neurological symptoms like dizziness, tremors, paresthesia, excessive sleeping, hearing difficulties, tremors, visual difficulties, and loss of taste were reported. Skin conditions like contact dermatitis was seen in 10 (7.6%) of our study population could also result from physical contact with mercury. One case of knee joint arthritis from wound contamination with elemental mercury was seen in Batouri.

Table 12. *Symptoms of mercury toxicity*

Variable	Batouri N (%)	Kette N (%)	Ngoura N (%)	Bétaré-Oya N (%)	Total N (%)
Symptoms					
Headache	10 (30.3)	7 (21.2)	9 (27.3)	7 (21.2)	33 (55%)
Unusual tiredness	7 (20.0)	8 (22.9)	10 (28.6)	10 (28.6)	35 (58.3)
Cough	6 (35.3)	6 (35.3)	3 (17.6)	2 (11.8)	17 (28.3)
Excessive sleeping	1 (20.0)	1 (20.0)	2 (40.0)	1 (20.0)	5 (8.3)
Dizziness	3 (27.3)	1 (9.1)	3 (27.3)	4 (36.4)	11 (18.3)
Tremors	6 (85.7)	0	1 (14.3)	0	7 (11.7)
Pins and needles	7 (31.8)	2 (9.1)	7 (31.8)	6 (27.3)	22 (36.7)
Hearing difficulties	1 (50.0)	0	1 (50.0)	0	2 (3.3)
Visual difficulties	5 (55.6)	2 (22.2)	1 (11.1)	1 (11.1)	9 (15)
Loss of taste sensation	4 (66.7)	0	0	2 (33.3)	6 (10)

PREVENTIVE AND CORRECTIVE MEASURES

6.1 Introduction

The development of recommendations (preventive and corrective measures) in this study was guided by the theoretical model of the International Labor Organization Guidelines on Occupational Health and Safety management system (ILO-OSH 2001). This model is a practical tool designed by ILO for assisting organizations and competent institutions as a means of achieving continual improvement in OHS performance. Most developing countries including Cameroon derive their OHS legislative and regulatory systems from ILO and are consistent with the ILO-OSH 2001 model. The model has been chosen for this study because it is free and easy to apply in the management of OHS.

There are five main elements of the model all operating in a continual improvement process and include (figure 11):

- Policy
- Organizing
- Planning and implementation
- Evaluation
- Action for improvement.

Figure 11. *The ILO-OSH 2001 model.*

6.2 Proposed recommendations

The proposed corrective and preventive measures are applicable to all artisanal and small-scale gold mining workplaces located in the East Region of Cameroon. The measures were formulated based on the findings from the current study and guided by the ILO-OSH 2001 model.

Figure 13. Proposed preventive and corrective measures

ILO-OSH 2001 element	Brief description of element	Findings from this study (problem)	Proposed recommendation
Policy	Every workplace should have an OHS policy aimed at protecting the H&S of all members, and complying with OHS standards.	• Most miners (70.9%) have poor knowledge of OHS. • Significant lack of awareness of the existence of a national OHS regulation in Cameroon. • Lack of a H&S policy in most (71.2%) workplaces	• Sensitization or awareness training of miners on H&S, and on the existence and compliance with national OHS rules and regulations. l • Training of mine owners on workplace policy development.
Organizing	Employers should assume full responsibility and accountability in OHS activities: protection of workers, periodic training, and proper documentation.	• Almost all miners (93.1%) did not know their duties and responsibilities concerning OHS. • significant proportion (88.1%) of workers had never been trained on OHS and labor was generally unskilled.	• Periodic training of miners and mine owners on OHS best practices.
Planning and implementation	This involves hazard identification and risk assessment, and implementation of preventive measures to eliminate, control or mitigate them where necessary.	• High to extreme risk of landslides due to unstable pit walls and undercutting of pit walls (poor mining techniques).	• Workplace designs implementation and training and empowering of miners with relevant skills and knowledge.
		• High to extreme risk of entrapment due to lack of adequate supports of tunnels, and lack of alternative exits.	
		• Moderate risk of rockfalls due to piling of overburden at pit wall edges.	
		• Moderate to High risk of falls due to existence of abandoned pits and untidy paths and ramps.	• Systematic refilling of pits after excavation, or access restriction to abandoned pits by senior management.
		• High risk of drowning due to existence of waterlogged pits.	

		• Extreme risk of gallery collapse due to tunneling in abandoned semi-mechanized pits and during the rainy seasons.	• Access restriction and/or systematic refilling of abandoned pits. • Access restriction to underground mining during the rainy season.
		• Inconsistent and low utilization (48.5%) of PPEs.	• Awareness training on the supply and use of PPEs.
		• High prevalence of malaria (59.5%) among other occupational illnesses	• Systematic refilling of abandoned pits. • Awareness training on systematic use of mosquito bed nets.
		• Risk of diarrheal conditions due to lack of proper hygiene, sanitation, and portable water at most mining sites.	• Supply of portable water points in communities. • Community education on proper waste disposal techniques.
		• Most injuries occurred as a result of lack of PPEs, lack of skills and expertise, and bad equipment.	• Awareness training of supply and use of PPEs. • Regular supply and maintenance of working tools. • Periodic training of miners on OHS best practices.
		• Detection of mercury in 71.7% of hair samples above the IRL, with high risk of mercury toxicity in long term if uncontrolled.	• Awareness training on regular supply and use of PPEs. • Awareness training on the supply and use of mercury retorts by amalgam burners.
Evaluation	Monitoring, measuring and recording of OHS performance on regular basis should be done, using selected performance indicators such as nature and magnitude of diseases and injuries.	• Lack of proper documentation of OHS indicators such incidence rates, fatality rates, prevalence of illnesses and diseases etc.	• Identification and training of focal persons for regular incidence investigation in all the four districts. • Establishment of clear system of reporting of OHS indicators from district to central levels
Actions for improvement	Arrangements should be established and maintained for preventive and corrective action resulting from the OHS management system performance, audits and management reviews.		Step-by-step Implementation of recommendations from this study, and arrangements for periodic auditing.

CONCLUSION

Globally though artisanal and small-scale mining is considered an activity of economic importance, it contributes significantly to the degradation of the health of gold miners and their families. This report describes the work that was undertaken in four artisanal gold mining districts in the East Region of Cameroon, aimed at assessing the health and safety risk of artisanal gold mining. The objectives, methodology, overview of the mining process, the health and safety risk, the causes of illnesses and work accidents, the level of exposure to mercury and preventive and corrective measures have been described. Work accidents, injuries and fatalities are an important concern in AGM, and as long as mercury is used in the AGM process, there is serious threat to the health of miners. An incorporation of fundamental principles of occupational health and safety and implementation of regulations governing this sector would contribute tremendously in reducing many of the health and safety problems.

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SPREAD SHEET OF RESULTS OF TOTAL HAIR MERCUR

Type of sample	Human Hair
Type of analysis	Methyl Mercury
Reference laboratory	Analytical Chemistry Laboratory of University of Michigan, USA
Number of sample bags	4
Total number of samples	60
Description of samples	Human hair samples of varying lengths (0.5 – 1 cm), and varying quantities (50 – 100 strands), contained within labelled pieces of tin foil, attached with a sticky tape at the distal end of the hair, and exposing the proximal (follicular) end of the hair, all contained within transparent zip-lock plastic bags containing desiccants. There are a total of sixty (60) samples within four (4) different labelled zip-lock plastic bags all contained within a 30x40 cm transparent zip-lock plastic bag as described below:

Bag label	Number of hair samples	Sample labels
BAG 1	18	BAH01 to BAH18
BAG 2	17	KEH01 to KEH17
BAG 3	12	COH01 to COH12
BAG 4	13	BOH01 to BOH13
Total	**60**	**60**

Analyzed by Helen Habicht via DMA-80 Total Hg Analyzer.

SAMPLE SPREAD SHEET

Date of sample collection	Sample number	Sample Code	Test result
		BAG 1	Total Hg (mg/kg)
29/05/2022	1.	BAH01	2.65
	2.	BAH02	1.66
	3.	BAH03	0.54
	4.	BAH04	0.56
	5.	BAH05	ND
	6.	BAH06	2.17
	7.	BAH07	ND
	8.	BAH08	1.37
	9.	BAH09	2.69
	10.	BAH10	3.62
	11.	BAH11	0.42
	12.	BAH12	2.82
	13.	BAH13	1.96
	14.	BAH14	3.23
	15.	BAH15	0.95
	16.	BAH16	3.21
	17.	BAH17	1.55
	18.	BAH18	ND
		BAG 2	
30/05/2022	19.	KEH01	1.02
	20.	KEH02	1.10
	21.	KEH03	0.45
	22.	KEH04	0.93
	23.	KEH05	1.92
	24.	KEH06	0.88
	25.	KEH07	0.66
	26.	KEH08	2.05
	27.	KEH09	0.42
	28.	KEH10	3.56
	29.	KEH11	1.07
	30.	KEH12	1.68
	31.	KEH13	1.65
	32.	KEH14	ND
	33.	KEH15	1.52
	34.	KEH16	1.88
	35.	KEH17	1.63
		BAG 3	
01/06/2022	36.	COH01	2.63
	37.	COH02	3.57
	38.	COH03	0.85

2

	39.	COH04	4.63
	40.	COH05	2.87
	41.	COH06	1.08
	42.	COH07	ND
	43.	COH08	3.27
	44.	COH09	3.69
	45.	COH10	2.22
	46.	COH11	3.35
	47.	COH12	1.43
BAG 4			
02/06/2022	48.	BOH01	1.55
	49.	BOH02	8.97
	50.	BOH03	0.79
	51.	BOH04	1.78
	52.	BOH05	2.75
	53.	BOH06	8.34
	54.	BOH07	0.94
	55.	BOH08	2.24
	56.	BOH09	1.12
	57.	BOH10	2.13
	58.	BOH11	2.42
	59.	BOH12	2.81
	60.	BOH13	8.16

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