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Analysis of Factors Associated with Occupational Accidents among Miners Scuba Divers: An Analytical Study in the Mining Centers of Banalia in the Province of Tshopo

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Abstract

Introduction: Mining, regardless of its scale, poses health risks to workers. We conducted this study to determine the factors associated with occupational accidents among miners in the Banalia region of Tshopo province. **Methods:** A cross-sectional study with an analytical aim was conducted among 422 people living in 2 mining households in the territory of Banalia, selected by the systematic sampling technique, during the period from March 18 to June 14, 2024. The analysis of the factors associated with occupational accidents was done using OR with confidence interval of 0.05. **Results:** The average age of the respondents was 38.2 ± 6.9 years; secondary education level (65%), married marital status (46%) and seniority of 10 years or more (81%) were dominant. The most observed diseases differently from others were malaria (83%) and STIs (67%) and the dominant health problems were low back pain (74%) and chest pain (73%). 74% of subjects had already experienced an occupational accident and 24% did not have good quality personal protective equipment (PPE). Poor quality PPE doubled the risk of accidents in the aquatic mining site (OR = 2.21 CI95: 1.4 - 3.8) and respecting the maximum duration of 2 hours in the water reduced the risk of accidents (OR = 0.32 CI95: 0.2 - 0.5). **Conclusion:** The quality of PPE and the regulation of diving duration must be followed to reduce the risk of accidents in mining areas.

Keywords

Occupational Accident, Mining Outbreak, Associated Factors, Banalia, DRC

1. Introduction

Mining, regardless of its scale, poses significant risks to the health of workers, surrounding communities, and the environment in general. Artisanal and small-scale mining (ASM) is of particular concern, representing a significant portion of global mining activity. It is characterized by precarious working conditions, a lack of regulation, limited access to healthcare, and the use of often rudimentary and dangerous techniques [1].

Mine safety refers to all the activities involved in maintaining and monitoring mining operations, and the tools or instruments used to reduce risks to individuals and the operating structure [2].

The hazards present in mines expose workers to health and safety risks that can lead to occupational illness or fatal injury. Ground instability is one of the leading causes of death in underground mines in Ontario. Since 2000, ten workers have died and nearly 50 workers have been seriously injured in Ontario underground mines due to landslides or ground shaking [2].

Globalization and the digital revolution have been transforming the world of work for more than twenty years, leading to greater flexibility in employment at the expense of job security. In this context, working hours, which had been in overall decline since the beginning of the 20th century, are now increasing. Worldwide, the number of people working more than 55 hours per week has increased over the last two decades, from an average of 8.1% of the working population in 2000 to 8.9% in 2016. In studies, the 55-hour workweek limit is predominantly used because this definition has been observed to be associated with negative impacts on health [3].

According to the directive specific to temporary work, the responsibility for protecting the health and safety of temporary workers is shared by both the legal employer and the user company. However, it is explicitly stated that "Member States shall take the necessary measures to ensure that the user company and/or establishment are, for the duration of the assignment, responsible for the conditions under which the work is carried out; the conditions under which the work is carried out shall include, but are not limited to, those relating to safety, hygiene and health at work" [4].

Health risks in mining areas are diverse and include factors such as age (mining children), gender (women), lack of personal protective equipment (PPE), and ignorance of protective measures [5].

Of particular concern among these risks is exposure to chemicals such as mercury and cyanide, which are used in amalgamation and gold mining. These substances can be inhaled, absorbed, or ingested, leading to serious health problems [6]. In addition, the use of power-driven machinery in confined spaces increases the risk of poisoning due to insufficient ventilation [7].

The most common biological diseases in these settings include vector-borne and water-borne infections, as well as sexually transmitted infections such as HIV/AIDS

and tuberculosis. These risks are exacerbated by crowded conditions and poor water and sanitation infrastructure, which is often inadequate in mining camps [8]. Stagnant water in these environments promotes the breeding of mosquitoes, vectors of diseases such as malaria and dengue fever [9].

Musculoskeletal disorders are also common among miners, often caused by heavy lifting and inappropriate postures while working [7]. Additionally, trauma resulting from rockfalls, explosions, and improper use of equipment are ever-present hazards, leading to biomechanical and other trauma injuries [10].

The International Labour Organization (ILO) estimates that approximately 1 million children aged 5 to 7 are involved in small-scale mining activities worldwide [11] Their participation, which covers all stages of ASGM, is often considered one of the "worst forms of child labour" according to ILO Convention No. 182. Eliminating this practice is complex due to its family-based, temporary and informal nature, as well as the associated levels of poverty [11].

In the Democratic Republic of Congo, studies conducted by the United Nations Environment Programme (UNEP) in 2016 revealed that the mining sector contributes to pollution, deforestation, and biodiversity loss, while posing security problems for local populations [12].

ASM in the Aruwimi Basin, Tshopo Province, is a vital economic activity for many communities. Miners, often seasonal and from diverse backgrounds, often work as part of their families, increasing their vulnerability to health risks [13]. The low income generated by EMAPE increases this vulnerability, with negative consequences for the health of workers and surrounding populations [13].

Evacuations for landslide accidents, drowning, respiratory infections, the increase in cases of diarrhea, the high frequency of STIs/AIDS and the recurrence of meningitis epidemics in the mining concentrations of Panga, fishing and Mangi in the territory of Banalia, where the victims are more the diggers or divers [14], motivate us to conduct this study to try to answer the question. "What are the factors associated with occupational accidents in the aquatic mining centers of the Aruwimi basin in the DRC?"

The objective of this study was to determine the factors associated with occupational accidents among underwater diving minors in the Banalia territory in Tshopo province.

2. Materials and Methods

2.1. Study Site

This study was conducted in the aquatic mining areas of the Banalia territory, located 128 km from the city of Kisangani. The Banalia territory has an estimated population of 332,681 inhabitants [14] spread over an area of 24,430 km^2; it is full of several aquatic exploitation centers, the most important of which are Panga and Pêcherie. (**Figure 1**)

The study was conducted in two mining areas of Panga and Pêcherie.

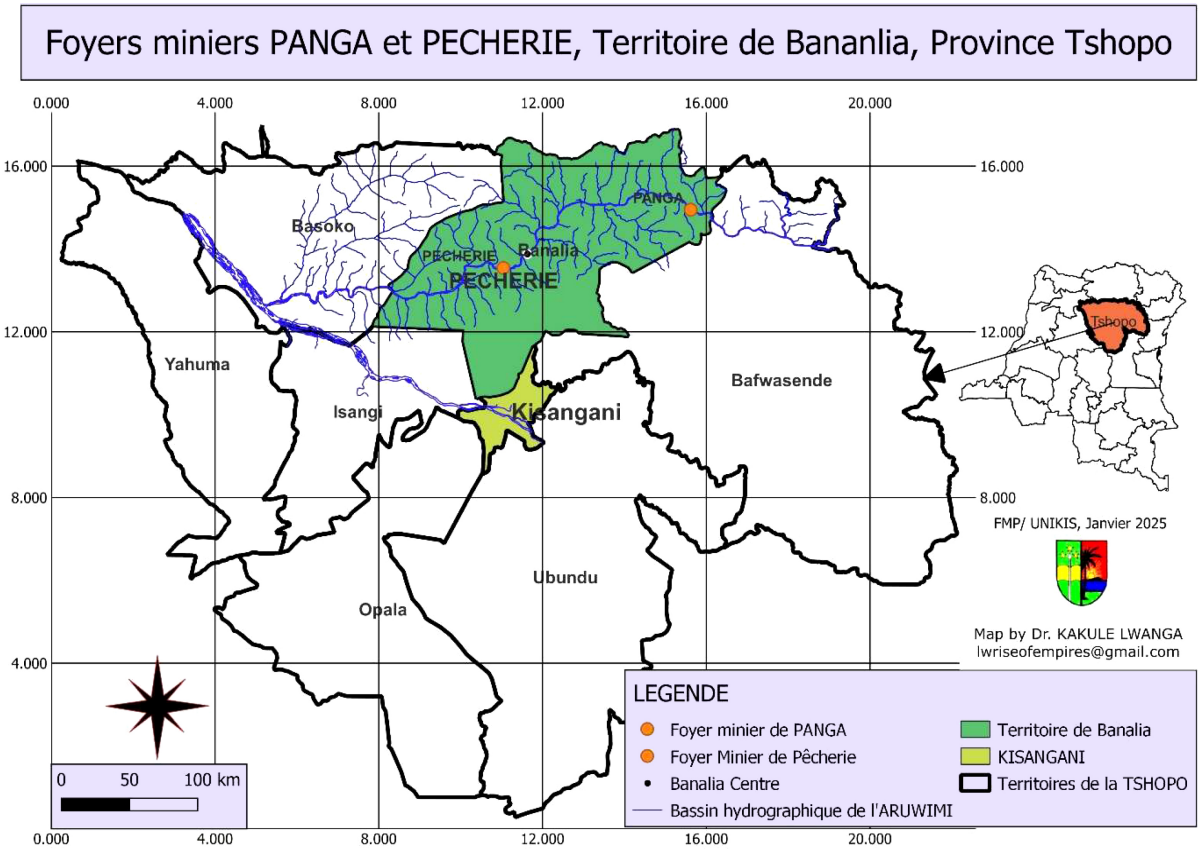

Figure 1. Study site mapping. (Source: Public Health, University of Kisangani)

2.2. The Study Population

It is made up of the inhabitants of mining communities, including local authorities and divers. The population of mining operators is not known due to a lack of census data and their constant mobility.

2.3. Type and Period of Study

A cross-sectional study with analytical aims was conducted during the period from March 18 to June 14, 2024.

2.4. Sampling

To determine the number of subjects to be included in the study, we used the SCHWARTZ formula as follows:

$$n = Z2\ p^*q/d2.$$

Considering Z = 1.96; p as the proportion of people exposed to risk in the mining environment, which is unknown (0.50), with the margin of error (d) estimated at 0.05 and an anticipated non-response rate of 10%, the sample size will be 422 subjects.

These 422 were distributed in the two most populated mining camps: PANGA and PECHERIE, in proportion to their size.

These camps were built in the form of large, non-urbanized villages. They give the inhabitants more or less stable addresses despite the lack of control over their population in periodic mobility. This allowed us to use the systematic sampling technique which was operated as follows: simple random drawing of 15 avenues of two camps (9 in PANGA and 6 in PECHERIE); counting of housing units on each avenue drawn (N); calculation of sampling interval (k) by dividing the number (N) by 28; identification of the first household to be surveyed by the random choice of a number between 1 and k; progressive addition of sampling intervals up to the number required per avenue. Two additional households were added to reach 422.

2.5. Data Collection Technique

Data were collected using a questionnaire embedded in the smartphone using Kobo collect software. This questionnaire was pre-tested on 5% of the expected subjects, or 21 people, living in the non-sampled avenues. This allowed us to re-adjust our questionnaire and validate it before its widespread use. We used guided interviewing using a questionnaire and direct observation of habitat conditions, state of PPE, technique and duration of diving using an observation guide developed for this purpose.

2.6. Data Analysis Technique

The data collected using smartphones were organized into an Excel database that was exported to STATA 5 for analysis. The search for factors associated with occupational accidents in mining sites was carried out by bivariate analysis with dichotomized variables, and the Odds Ratio (OR) was calculated with confidence intervals at the 5% threshold.

2.7. Operational Definition of Main Variable

Occupational accidents: Any health problem occurring during or in the hours following work in aquatic sites and which can be linked to mining activities was considered an occupational accident.

2.8. Ethical Considerations

This study received authorization from the ethics committee of UNIKIS, the DPS and the Banalia territorial administration.

Participation in the study was voluntary with informed consent, and data analysis and dissemination were anonymous.

3. Results

The mean age of aquatic miners was 38.2 ± 6.9 years, with the dominant age range being 41 to 45 years; secondary education and married marital status were dominant. The median duration of work by miners in our study was 10 years or more. (Table 1)

Table 1. Socio-demographic characteristics of respondents.

Characteristics N = 422	Terms and conditions	Frequency	Percentage
Age (mean ± SD)	38.2 ± 6.9		
Age group (years)	16 to 25	18	4
	26 to 30	37	9
	31 to 35	107	25
	36 to 40	80	19
	41 to 45	114	27
	46 to 50	66	16
Educational level N = 422	None	11	3
	Primary	21	5
	Secondary	281	65
	Higher and university	109	26
Marital status	Bachelor	87	21
	Married	195	46
	Free union	128	30
	Divorced/Separated	12	3
Length of career Median (p75 p25)	14 (17 - 10)		
	1 to 3	12	3
	4 to 9	67	16
	10 and over	340	81

The most commonly observed illnesses, different from others, were malaria and STIs, and the dominant health problems were lower back pain and chest pain. The dominant symptoms upon leaving the dishwasher were dizziness, pain, and chills. Nearly three-quarters of the patients had already suffered occupational accidents and had good-quality PPE. (Table 2)

It is evident from this table that poor quality PPE increased the risk of accidents in the aquatic mining site twice (OR = 2.21 CI95: 1.4 - 3.8) and the duration of immersion of 1 to 2 hours in the water reduces the risk of accidents (OR = 0.32 IC95: 0.2 - 0.5). (Table 3)

Table 2. Epidemiological profile in mining sites.

Characteristics N = 422	Terms and conditions	Frequency	Percentage	95% CI
Common illnesses/health events at mining sites	Malaria	349	83	79 - 87
	Diarrheal diseases	196	46	41 - 51
	IRA	230	55	50 - 60
	IST	293	69	65 - 73
	Trauma	153	36	31 - 41
	Death without apparent cause	147	35	30 - 40
	Rash diseases	103	24	30 - 40
	Meningitis	128	30	26 - 34
Health problems experienced by miners	Weight loss	68	16	13 - 19
	Lack of appetite	64	15	12 - 18
	Cramp	211	50	45 - 55
	Chest pain	307	73	69 - 77
	Abdominal pain	172	41	36 - 46
	Low back pain	313	74	70 - 78
	Sexual weakness	84	20	16 - 24
	Skin alteration	82	19	15 - 23
	Visual disturbances	62	15	12 - 18
Dominant complaints when leaving the water after diving	Vertigo	247	59	54 - 64
	Vomiting	139	33	29 - 37
	Loss of consciousness	141	33	29 - 37
	Pain	250	59	54 - 64
	Thrill	218	52	47 - 57
Have you ever had a work-related accident?	Yes	312	74	70 - 78
	No	107	26	22 - 30
Possession of PPE N = 422	Yes	416	99	98 - 100
	No	2	1	0 - 0.02
State of the EPI N = 416	Good	325	78	74 - 82
	Bad	91	22	18 - 26

Table 3. Analysis of factors associated with occupational accidents in aquatic mining sites.

Independent variables	Occupational accident		GOLD	95% CI	P value
	Yes N = 312	No N = 107			
Intake of alcoholic beverages			1.32	0.74 - 2.35	0.346
Yes	264	87			
No	46	20			
Smoked			0.905	0.56 - 1.46	0.682
Yes	210	75			
No	99	32			
Professional seniority			0.337	0.67 - 1.69	0.166
1 to 5 years	3	3			
More than 5 years	309	104			
Quality of PPE			2.21	1.4 - 3.8	0.001
Good	55	36			
Bad	251	71			
Dive duration			0.315	0.2 - 0.496	0.001
1 to 2 hours	97	63			
More than 2 hours	215	44			

4. Discussion

4.1. Sociodemographic Characteristics of the Respondents

The mean age of aquatic miners was 38.2 ± 6.9 years, with a predominance of workers aged 41 to 45 years (Table 1). In another's studies conducted in Ghana, the binary logistic regression model had also shown that socio-demographic variables such as age, marital status, religious status and level of education of respondents significantly determined their participation in illegal mining activities [15] [16]. The average ages observed in our study and the level of education are comparable to the result of above-mentioned studies which identify health risk factors in mining areas.

The dominant level of education was secondary (65%), a finding that corroborates data from the International Labour Organization (ILO) indicating that the majority of workers in artisanal mines have a limited level of education, which reduces their ability to understand and apply occupational risk prevention measures [12].

4.2. Epidemiological Profile in Mining Sites

Malaria was the most common disease (83%), followed by sexually transmitted

infections (69%), acute respiratory infections (55%) and diarrheal diseases (46%) (Table 2). The high incidence of malaria in mining areas is explained by an environment characterized by stagnant, unchanneled water that becomes a breeding ground for mosquitoes, the limited use of insecticide-treated mosquito nets (LLINs), and the overcrowding of living spaces, which provides ideal hiding places for mosquitoes. In addition, insufficient use of antimalarial drugs increases plasmodial parasitaemia. This corroborates the results published by the WHO [17]. Actions to promote a clean environment and the use of LLINs are necessary.

Sexually transmitted infections (STIs) were very common (69%) in mining environments (Table 2). This is justified by the risky sexual behavior in the mines characterized by sexual promiscuity and unprotected sex, on the one hand, and drug use and prolonged sedentary lifestyle, on the other. This corroborates the observations of PEPFAR in the Democratic Republic of Congo (DRC), which attributes the high prevalence of STIs/AIDS in mines to the high mobility of workers and the lack of awareness about risky sexual behavior [18]. The awareness program should address this aspect to ensure the promotion of responsible sexual behavior and increase the demand, access and availability of condoms in mining households.

Trauma was also common (36%) (Table 2), reflecting the inherent hazards of mining work. Fatal accident were reported at mining sites, the main causes of which were poor working, unstable ground, equipment or machinery problems and the absence of safe operating procedures or inappropriate operating procedures [19].

4.3. Analysis of Factors Associated with Occupational Accidents in Aquatic Mining Sites

The study found that 74% of mine operators had already experienced an occupational accident. One of the determining factors was the quality of personal protective equipment (PPE). Workers using poor-quality PPE had a twice-high risk of an accident (OR = 2.21; 95% CI: 1.4 - 3.8) (Table 3). This observation highlights the importance of a policy of distribution and maintenance of PPE in artisanal mining areas [19].

Another significant factor was the duration of 1 to 2 hours of diving in the water, which was a factor against accidents (OR = 0.32 IC95: 0.2 - 0.5).

The International Council on Mining & Metals (ICMM) highlights that prolonged exposure to aquatic environments can lead to serious physiological disorders, thus increasing the risk of accidents [20].

Finally, the use of psychoactive substances such as alcohol and tobacco has not been shown to be associated with occupational accidents. Within the limitations of self-reporting by participants on the consumption of psychoactive substances such as alcohol and tobacco, recognized as risk factors, there is a possibility of measurement bias or under-reporting by study participants.

Results from other research, including those of Calys-Tagoe *et al.* in Ghana, had

identified alcohol consumption as a potential risk factor due to reduced alertness and delayed response to dangers [21] [22]. This controversy needs to be explored in another study.

5. Conclusion

Mining sites are characterized by a high prevalence of infectious and musculoskeletal diseases, which are fueled by the physical and socio-professional environmental conditions of the mines. Occupational accidents are fueled by the poor quality of protective equipment used and excessive diving time. It is essential to disseminate and enforce regulations on occupational health and safety in mining sites.

6. Limitations of the Study

The validity of our data does not exclude the possibility of observing possible changes in the epidemiological profile under the influence of the seasonality of mining activities.

The cross-sectional design of the study, the use of self-reported data and the lack of control over potential confounding variables also constitute limitations for this study.

The insufficiency of factors likely to influence occupational accidents in mines, with the possibility of measurement bias or under-reporting, did not allow for a multivariate analysis to be carried out to control confounding factors and provide information on independent predictive factors.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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