# Perception of the ecological and health risks associated with artisanal gold mining in Burkina Faso: the case of the Loto site in the southwest.

**Ylassa DJENDA[1*], Alphonse Maré David MILLOGO[2], Ibrahim KONATE[1], Mipro HIEN[1,3]**

## Abstract

Although a major source of income for vulnerable communities, especially in rural areas, artisanal gold mining has a negative impact on the environment and health, and is a source of conflict. Faced with this situation, knowledge of the factors determining the risks of this practice could contribute to better management of environmental and human health. For this reason, this study sets out to analyse the perception of risks associated with artisanal gold mining in Loto, in south-west Burkina Faso. To achieve this objective, surveys were carried out with one hundred and fifteen (115) people, including artisanal miners and local and administrative authorities. Data analysis was based on the weighted average method to calculate risk perception indices, and a logistic regression model was used to assess risk perception susceptibility. The results showed that gold miners perceived the risks of gold panning with an overall average index of 0.6. The factors that most influence risk perception are education, awareness, age, occupation, experience, motivation and/or reasons, and trauma. In addition, surveys have shown that artisanal gold mining leads to vegetation loss, soil degradation, pollution of water sources and dust proliferation. The main risks of serious accidents that can cause death are landslides, trauma, drowning and explosions (by blasting). In addition, the main illnesses encountered are trauma-related, fevers, malaria, digestive and respiratory problems, and sexually transmitted infections. The results of this study could contribute to the implementation of sustainable development policies in general, and public health policies in particular.

**Key words**: Perception, risks, gold panning miners, Loto, Burkina Faso.

[1]Laboratory for Bioresources, Agrosystems and Environmental Health (LaBASE), University of Nazi BONI, Bobo-Dioulasso, 01 BP 1091 Bobo-Dioulasso 01 Burkina Faso

[2] West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), Graduate Research Program on Climate Change and Disaster Risks Management, Faculty of Human and Social Sciences, University of Lomé, Lomé, Togo. B.P. 1515. Lomé, Togo

[3] National Tree Seed Centre (CNSF), Ouagadougou, 01 BP 2682, Burkina Faso

***Corresponding author**: Ylassa DJENDA, Tel: +226 79 44 93 73. Email: ydjenda@yahoo.com

## Perception des risques écologiques et sanitaires liés à l'exploitation artisanale de l'or au Burkina Faso : cas du site de Loto dans le Sud-Ouest.


### Résumé

Bien qu'une source de revenus importants pour les communautés vulnérable surtout en milieu rural, l'exploitation artisanale de l'or impacte négativement sur l'environnement, la santé et est source de conflits. Face à cette situation, la connaissance des facteurs déterminants les risques de cette pratique pourrait contribuer à une meilleure gestion de la santé environnementale et humaine. C'est pourquoi, cette étude se propose d'analyser la perception des risques liés à l'exploitation artisanale de l'or à Loto dans le Sud-Ouest du Burkina Faso. Pour atteindre cet objectif, des enquêtes ont été menées auprès de cent quinze (115) personnes composées d'artisans miniers, d'autorités communales et administratives. L'analyse des données s'est basée sur la méthode de la moyenne pondérée pour calculer les indices de perception des risques et un modèle de régression logistique a permis d'évaluer la susceptibilité de la perception des risques. Les résultats ont montré que les orpailleurs percevaient les risques de l'orpaillage avec un indice moyen global de 0,6. Les facteurs qui influencent le plus la perception des risques sont l'éducation, les sensibilisations, l'âge, les occupations, l'expérience, la motivations et/ou raisons et les traumatismes. En outre, les enquêtes ont montré que l'exploitation artisanale de l'or entrainait des pertes de végétation, la dégradation des sols, des pollutions des sources d'eau et la prolifération de poussières. Aussi, les principaux risques d'accidents graves pouvant causer des décès sont les éboulements, les traumatismes, les noyades et les explosions (par dynamitage). Par ailleurs, les principales maladies rencontrées sont celles liées aux traumatismes, les fièvres, le paludisme, les problèmes digestifs et respiratoires et les infections sexuellement transmissibles. La prise en compte des résultats de cette étude pourrait contribuer à la mise en œuvre de politiques de développement durable en générale et de politiques de santé publique en particulier.



**Mots clés** : Perception, risques, orpailleurs, Loto, Burkina Faso.


# Introduction

Gold panning is a poor organised and mechanised gold extracting practice at a small scale (UNEP, 2012; TYCHSEN et al., 2019). This practice is an important source of income, particularly for rural communities for whom economic alternatives are often non-existent or extremely limited (BOHBOT, 2017; IGF, 2017). In Africa sub-Saharan region, gold panning is the most important rural economic activity (RICHARD et al., 2015; TYCHSEN et al., 2019), after agriculture. Despite the major economic stakes involved, this activity negatively affects the environment, life quality and leads to critical health risk for local populations (TOMICIC et al., 2011; TYCHSEN et al., 2019).

Gold panning activities contribute to soil degradation, deforestation, water and air pollution, health and safety issues (ELHASSAN et al. 2014; WADI & ALREDAISY, 2015; TYCHSEN et al., 2019; NDIAYE, 2020).

Gold panning miners face many risks including biological, chemical, biomechanical and physical risks (WADI and ALREDAISY, 2015; TYCHSEN et al., 2019; FAO, 2021). In addition, a lack of organisation among stakeholders, as well as land tenure issues, sometimes leads to conflicts that can cause deaths and many injuries (GRÂTZ, 2002; REICHEL (2018); MEGRET et CROS, 2018; FAO, 2021; HUNTER, 2022). Despite facing numerous risks, gold panning miners do not plan for rehabilitation actions or adhere to health and safety measures. As a result, they are often involved in accidents that can lead to death, permanent disability, or a decline in their overall health and well-being (WADI and ALREDAISY, 2015). In Burkina Faso, this phenomenon is increasing in the Southwest region that hosts the most important number of gold panning sites and miners (INSD, 2017). Considering the numerous risks associated with gold panning activity, it appears necessary to improve knowledge of gold panning risk determinants for environment sustainable management and human health. To fill the gap of knowledge on gold panning risk determinants factors, the current study "the perception of risks associated with gold panning" was initiated. This study is based on various risks, frequencies and associated probability perceived by gold panning miners. According to ARMAH et al. (2020), the risks associated with gold panning are more frequent than gold panning miners' expectations. This poor perception from gold panning miners justifies the numerous risks that they are exposed to, because of miss coping measures adopted. This study aims to improve knowledge on various risks associated to gold panning for better environmental and human health care disaster risk management. Specifically, the study seeks to identify: 1) the main ecological and health risks associated with gold panning and 2) the determinant factors perceived of risks associated with gold panning.

# I. Material and methods

## I.1. Material

### I.1.1. Presentation of the study area

The study was carried out at the Loto, a village located in the Diebougou commune in south west Burkina Faso. Loto is located at latitude 10°56'44" north and longitude 3°17'16" west (Figure 1). The

municipality of Diebougou belongs to the South-Sudanian climate region where the vegetation is characterised by wooded savannah, open forests and forest galleries along permanent watercourses (FONTES J., & GUINKO S., 1995). Hydromorphic, compact, low-permeability soils and poorly leached and leached tropical ferruginous soils are commonly encountered. The hydrographic network is strongly dominated by the Bougouriba, a tributary of the Mouhoun, to which numerous temporary watercourses and ponds have been added. The commune's economic activity is based mainly on agriculture, fishing, livestock farming, industry, crafts and trade. The population of the Diebougou commune is estimated at 63,304, including 31,749 women in 2019 (INSD, 2021). With an estimated surface area of over 100 hectares by communities, Loto is a mixed site comprising a quarry area in the mountains, a processing area and a commercial and residential area. In addition, Loto locality is the last to be set up and the largest in the municipality, with more than 2,000 gold panning operators.

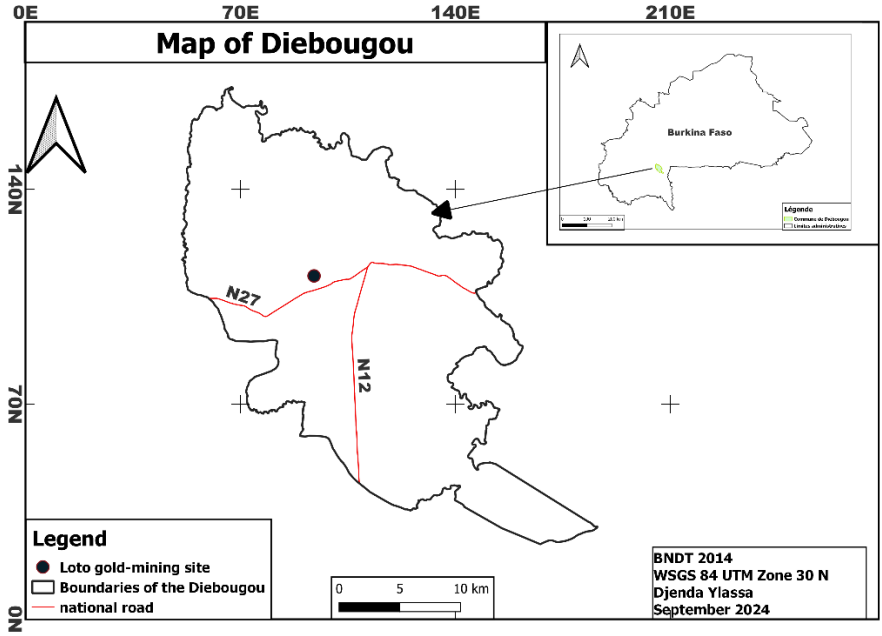


**Figure 1**: Study area location

## I.1.2. Data collection

The surveys were carried out in February 2023. They included both quantitative and qualitative data. They were collected from gold miners, households, agents of deconcentrated technical services (environment, mines, health), communal authorities and local elected representatives.

Artisanal miners and households were surveyed using a questionnaire. Semi-structured interviews were conducted individually with decentralised public administration resource persons, customary authorities and local councillors. Respondents were at least eighteen (18) years old. Table I presents the details of the sampling. The data collected mainly concerned the socio-economic characteristics of the respondent, various types of environment and health issues associated with gold panning, and adaptation measures to cope with issues. The questionnaire was conducted using the Kobo toolbox to facilitate data collection and processing.

**Table I:** Sampling distribution

| **Respondents** | **Number** | **Percentage** |
|---|---|---|
| Gold panning miners | 45 | 39.13 |
| Households | 60 | 52.17 |
| Local elected representatives | 1 | 0.87 |
| Environment department staff | 4 | 3.48 |
| Healthcare staff | 2 | 1.74 |
| Mining workers | 1 | 0.87 |
| Local authorities | 2 | 1.74 |
| **Total** | **115** | 100 |

**Source :** Author, based on survey data

Socio-economic, demographic and environmental data were used to determine risk perception (Table II). The data were chosen based on their relevance to our study and because they are widely used in the literature to influence the perception of risks associated with gold panning (MAHMOUD et al., 2020; ARMAH et al., 2016 and ELIAS et al., 2013).

**Table II** : Data likely to influence risks perception related to gold panning

| Data | Coding | Regression measurement | Assumptions |
|---|---|---|---|
| Old (years) | [18-25] (1), ]25-35] (2), ]35-45] (3), ]45-60] (4) and >60 (5) | Continuous | Older people tend to perceive the risks associated with gold panning better than younger people. |
| Gender | Male (1) and Female (2) | Nominal | Women tend to perceive the risks associated with gold panning better than men. |
| Education | Out of school (1), Primary (2) et Secondary (3) | Nominal | People with school education tend to perceive the risks associated with gold panning better than people without school education. |
| Motivations/Reasons | Unemployment (4), No better option (5), Poverty (6), To support my parents/family (3), Wealth (1) and Infertile land (2) | Nominal | People living in poverty, unemployed people tend to perceive the risks associated with gold panning better than those motivated by wealth. |
| Experience (years) | <5 years (1), [5-15] (2), [16-30] (3) and >30 (4) | Continuous | A greater number of years in work is linked to an increase in perceived risk. |
| Origin | Allochthonous (1) and autochthonous (2) | Nominal | People from the gold panning area tend to perceive the risks associated with gold panning better than those from outside the area. |
| Occupation | Farmer (1), shopkeeper (2), mining craftsman (3) | Nominal | Gold panning miners are more exposed to the risks associated with gold panning than farmers and shopkeepers. |
| Monthly income (FCFA) | >50000 (3), [50000-100000] (2) et >100000 (1) | Continuous | Higher income is associated with reduced gold panning risks. |
| Effects on health | Yes (1) and no (0) | Nominal | Individuals who are aware of the impact of l gold panning on health and the environment tend to perceive the risk as significant |
| Protective measures | No (0) and Yes (1) | Nominal | People who wear protective equipment tend to perceive a high level of risk. |
| Risk of trauma | Likert scale: [1-5] = low (1), ]5-10[=high (2) and >10= very high (3) | Nominal | A large number of accidents increases the perception of the risks associated with gold panning. |
| Water quality | Good (1), fairly good (2) and poor (3 | Nominal | An individual with capacity to distinguish good quality water sources tends to perceive the risk of pollution from water sources as reduced. |
| Knowledge of regulations | Yes (1) and no (0) | Nominal | Individuals who are aware of the regulations about gold panning tend to perceive a high level of risk. |
| Awareness | Yes (1) and no (0) | Nominal | An individual who is aware about gold panning effects is likely to perceive the significant risks. |
| Main activity | Yes (1) and no (0)) | Nominal | A professional gold panning miner tends to perceive the risks of gold panning as significant. |

## I.2. Method

### I.2.1. Data collection method

As the artisanal gold mining sites are informal, the gold miners are reluctant to be interviewed. So, to make our surveys a success, we sought the assistance of the site manager and the village development adviser for the village of Loto. These people are well known to the farmers. The sampling method consisted of surveying one artisanal miner every ten meters, randomly on either side of the site's alleys. In the village, the head of household of one concession in three was surveyed. The sample size was determined using the formula in REA (1997) : $\boldsymbol{n = \frac{tp^2 \times P\,(1-P) \times N}{tp^2 \times P\,(1-P) + (N-1) \times y^2}}$ ; where n is the sample size, N is the size of the target population, P is the expected response proportion (it's 50% by default), tp is the value of the 95% sampling confidence interval and y is the margin of sampling error equal to 5%. Our surveys involved 115 people.

### I.2.2. Data processing and analysis method

Data processing involved calculating perceived risk index and performing logistic regression. The quantitative results of the analyses obtained were supplemented by qualitative data. The qualitative data were used to explain the results of the quantitative data analyses and to place them in the context of our study.

### I.2.3. Method for calculating perceived risk indices

The Perceived Risk Index (PRI) provides a relative measure of risk perception for each individual. Higher values of the PRI indicate higher levels of risk perception. An index greater than or equal to 0.5 indicates perceived risk (MAHMOUD et al., 2019). We used the weighted average method to calculate the composite indices of risk perception related to artisanal gold mining for each individual interviewed. This method was applied by considering equal weights for each of the selected data; that is why, each variable was considered to have a weight equal to that of the perceived risk variable (ELIAS et al., 2013; MARCON et al., 2015; LONG et al., 2015; MAHMOUD et al., 2022). These weights were assigned to each modality of the data according to the level of vulnerability perceived by the respondent. In most cases, the modalities corresponding to the highest levels of vulnerability are assigned a weight of 1, while the least vulnerable are assigned a weight of 0 (ARMAH et al., 2016 and ELIAS et al., 2013). In the case of our study, for a variable with two modalities, the associated weights are 0

and 1, while for a variable with three modalities, the values are 0.33, 0.67 and 1. For data with four levels of modalities, the weights are 0.25, 0.50, 0.75 and 1. In all cases, the composite index obtained for each component is between 0 and 1. For the 'water quality' variable, the associated weights are the opposite. In fact, if a respondent perceives the quality of water sources to be "Poorer", then the highest weight is associated with it, i.e. 1. This is explained by the fact that for a respondent, compared with time and especially compared with the period before artisanal gold mining began, a perception of a reduction in the quality of water sources tends towards a significant perception of the risks of pollution of water sources. The following formula was used to calculate the perceived risk index: $\boldsymbol{IRP = \sum_{i=1}^{n} W_i / n}$ ; where IRP is the index of perceived risk, W1 to Wn are the weights associated with each variable modality and n is the total number of data used.

### I.2.4. Logistic regression method

The relationship between the perception of the risks of artisanal gold mining and the data selected was assessed using a binary logistic regression model (logit). The aim here was to explain the perception of the risks of artisanal gold mining on the environment and health, as well as conflicts, by so-called independent data (table II). This logistic regression was carried out in three stages: (i) The first stage consisted of testing for multi-collinearity between the explanatory data. A model containing all the predictors was constructed and the collinear data were identified using the VIF (Variance Inflation Factor) function. (ii) The second stage involved building a regression model containing the non-collinear data. The GLM (Generalized Linear Model) procedure was used. Theoretically, binary logistic regression consists of constructing a model linking the dichotomous or binary dependent variable (yes/no, perception or non-perception) and qualitative or quantitative independent data plus an error term called noise (TUFFERYP, 2017; AITKIN et al., 2005). (iii) The third step consisted of checking the significance of the data and selecting the data that were significant for risk perception. Significance was checked in R by applying an analysis of variance (ANOVA) to the logit model created in step 2. The "car" package was used for this check. On the other hand, the selection of significant data was carried out using the backward selection method based on the minimisation of the Akaike Information Criterion (AIC). The step function in the MASS package was used to obtain a reduced model containing only the significant data.

# II. Results

## II.1. Socio-economic profile of respondents

The majority of respondents were male (89.56%). Young people were the most numerous, with a minimum old of between 18 and 25 (43.47%). Some were older between 45 and 60, representing 9.56% of respondents. Most of the respondents did not attend school (46.95%). The majority of artisanal miners on the site have an average monthly income of less than 50,000 FCFA, representing 54.78%. Those with less than 5 years' experience in the field are more numerous, accounting for 60.87% of respondents.

**Table III:** Analysis of variances for Loto data

| Data | Estimate | Std. Error | Z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | -0.97323 | 1.97048 | -0.494 | 0.62137 |
| Old]25-35] years | 0.85329 | 0.66992 | 1.274 | 0.20276 |
| Old]35-45] years | 0.52015 | 0.78287 | 0.664 | 0.50642 |
| Primary_Education | -0.85262 | 0.65272 | -1.306 | 0.19147 |
| Secondary_Education | -1.17946 | 0.84617 | -1.394 | 0.16335 |
| Motivations/Reasons_For lack of a better word | -1.87542 | 1.03594 | -1.81 | 0.07024. |
| Motivations/Reasons_Poor | -1.18166 | 0.8772 | -1.347 | 0.17795 |
| Motivations/Reasons_Wealth | -2.75934 | 1.27595 | -2.163 | 0.03057 * |
| Experience <5 years | -0.71448 | 0.70422 | -1.015 | 0.31031 |
| Experience ]5-15] years | -2.84157 | 1.18648 | -2.395 | 0.01662 * |
| Occupation_Trade | 3.75468 | 1.396 | 2.69 | 0.00715 ** |
| Occupation_Gold_miners | 2.25655 | 0.80375 | 2.808 | 0.00499 ** |
| Monthly income<50000 | 0.53558 | 0.88104 | 0.608 | 0.54326 |
| Monthly income>100000 | 1.49805 | 0.68855 | 2.176 | 0.02958 * |
| Effects on vegetation_Yes | -0.77108 | 0.68332 | -1.128 | 0.25913 |
| Awareness_Yes | 3.05563 | 1.38275 | 2.21 | 0.02712 * |
| Trauma_Low | -1.6163 | 0.90356 | -1.789 | 0.07364. |

Significance of codes: 0.001 '**'=Very significant; 0.01 '*'=Moderately significant; 0.05 '.'=Significant and 0.1 ' ' 1= Not Significant

## II.2. Logistic regression analysis

Analysis of variance at the 5% threshold (table III) of the survey results showed that only the "occupation (gold panning and trading)" variable was highly significant ($p<0.001$). The moderately significant data ($p<0.01$) were "motivations or reasons (wealth), experience (5- 15 years), monthly income (>100,000) and awareness. The significant data ($p=<0.05$) were "motivations or reasons (no better) and trauma (low)".

## II.3. Effects of artisanal gold mining on environmental components

The respondents cited the effects of artisanal gold mining on the components of the environment (Figure 2). They unanimously perceived the loss of vegetation due to this practice. The frequency of respondents citing soil degradation due to artisanal gold mining was 58.83%. Water sources pollution was cited by 33.33%. Dust was cited by 7.84% of respondents.

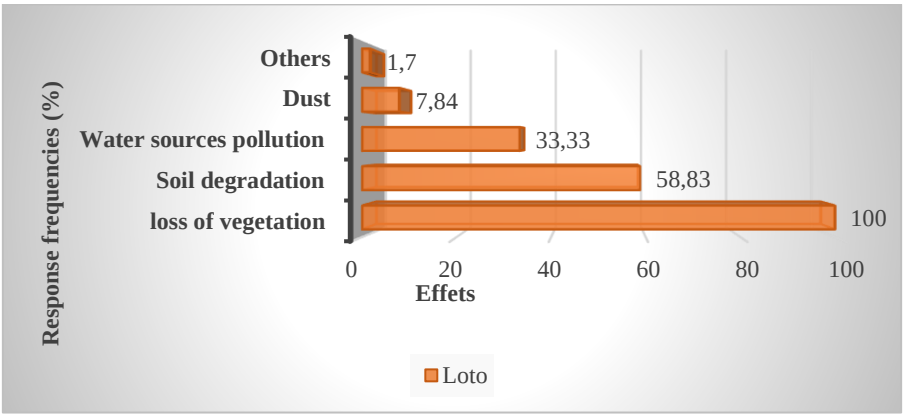


**Figure 2**: effects of gold panning on environmental components

## II.4. Effects of artisanal gold mining on health

The survey results showed that health problems increased with the installation of the artisanal gold mining site in the area (figure 3). Indeed, 86.6% of respondents cited respiratory problems, 78.13% malaria, 56.26% digestive problems, 45.45% trauma, 23.4% STIs/STIs, 18.18% fevers and 1.52% other types of illness (1.52%). Interviews with health staff at the Diebougou commune health centre showed that consultations increased with the installation of the site. The results also showed that the main reasons for consultations at the health centres, especially by gold miners, were injuries, malaria, fever, coughs and indigestion.

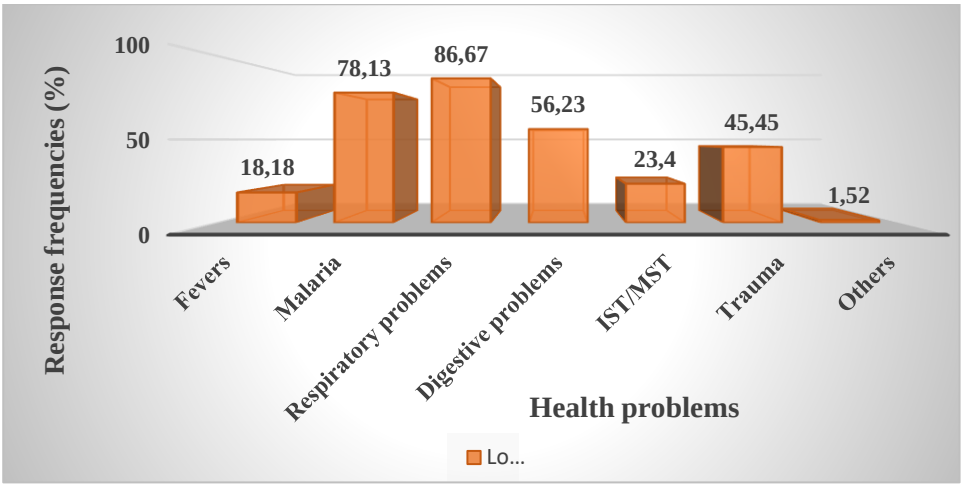


**Figure 3**: Main health risks

## II.5. Risk of serious accidents in gold panning operations

In the case of our study, the main risks of serious accidents (likely to cause death) were landslides and trauma, with response percentages of 89.15% and 78.26% respectively; followed by drowning (47.2%) and explosions (27.11%). Figure 4 shows the main risks of serious accidents.

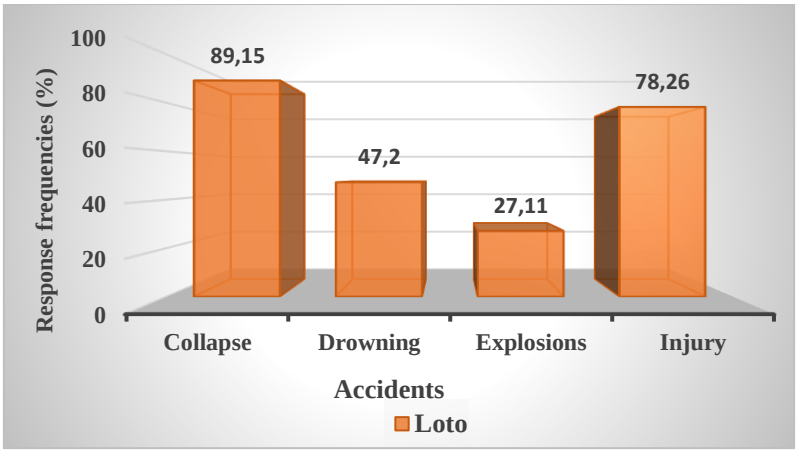


**Figure 4**: Main risks of serious accidents linked to gold mining

## II.6. Links between the risks of artisanal gold mining, health and the population

Based on the classification of types of risk associated with artisanal gold mining by the WHO (2017), analysis of the field results enabled us to make the link between types of risk, the main health problems

encountered by gold miners and the most vulnerable stratum of the population. Indeed, the WHO classifies the risks associated with artisanal gold mining into biological risks, chemical risks, biomechanical and physical risks, and others types of behavioural risks.

**Table IV** : Sets out the links between risks, health and vulnerable populations.

| **Type of risk** | **Health problems** | **Most vulnerable sections of the population** |
|---|---|---|
| Biological risks | Malaria | Migrants (men and women) living in precarious housing, pregnant women and children who do not sleep under mosquito nets. |
| | Digestive problems | All people living on the sites (men and women) in poor hygiene conditions, as well as children, who consume contaminated food and water. |
| | STI/HIV/AIDS | Men and women, generally migrants with high-risk behaviour and female sex workers. |
| Chemical risks | Chemical poisoning | People employed to wash gold (amalgamators) who are exposed during gold extraction work, pregnant women and children who consume contaminated food or water, as well as anyone living near work involving chemicals (mercury, cyanide, etc.). |
| | Acute respiratory problems | Mainly people employed in crushing and grinding, children accompanying their mothers and anyone exposed to dust as a result of artisanal gold mining. |
| Biomechanical and physical risks | Trauma | People employed in sinking, crushing and grinding operations. Also, injuries that occur on the roads leading to artisanal gold mining sites. |
| | Reproductive health | Pregnant women living on the sites run the risk of complications during pregnancy. |
| | Fatigue | All gold miners employed in all stages of gold extraction. |
| Other risks | Unwanted pregnancies | Sex workers and other women on the sites |

**Source**: Author, analysis of survey data

The number of people living in areas where artisanal gold mining takes place is increasing, especially in the more profitable sites, which would

increase the risk of disease in these areas. Health decision-makers could use the results of such a study to develop effective health policies to prevent certain diseases. Table IV shows the links between risk, health and vulnerable populations.

### II.7. Perceived risk indexes

The fifteen data previously identified in table 2 were used to calculate the risk perception indices for artisanal gold mining. The overall average risk perception index is 0.60. Consequently, all respondents are likely to perceive the risks of artisanal gold mining.

## III. Discussions

The rise in the price of gold in the 2000s led to a rush of people to artisanal gold mining sites. During this period, the sector recorded a large number of people on the sites. Today, that number depends on the gold found. Various categories of people work on the sites. Some are there to find funds to start an income-generating activity, while for others it's the quickest way to make money and become rich. The length of time a mining site can be exploited depends on the amount of gold available. As a result, gold miners are prepared to abandon a site when the gold is no longer sufficiently available or when they learn of the discovery of a new, more lucrative site. In this way, gold panners are like migrants guided by the availability of gold, exposing them to all kinds of risks associated with this practice (IOM, 2019).

### III.1. Effects of artisanal gold mining on environmental components

As the Loto site is informal, the work is neither planned nor does it have a rehabilitation plan. As a result, the plant cover has been destroyed, and watercourses, soil and air have been polluted. At Loto, gold miners cut wood and use it to support their galleries and hangars. This leads to degradation of the ecosystems and their services and goods, loss of biodiversity and, ultimately, severe erosion and irreversible sterilisation of the soil through the disappearance of the humus-bearing horizon. Gold mining practices, which involve digging holes and scraping the soil, lead to the stripping of topsoil. This increases compaction and results in the loss of nutrients and soil structure. In addition, the chemicals used in the gold extraction process, such as mercury and cyanide, as well as the waste oil from crushing machines and other equipment, cause water, soil and air pollution. Not only do these products pollute the soil, rendering it infertile, but they also end up in waterways, contaminating them and rendering them unsuitable for

consumption, thereby endangering aquatic organisms and the health of animals and humans. This explains the high response percentages for biodiversity loss (100%), soil degradation (58.83%) and water pollution (33.33%). These findings corroborate those of OUMAR et al. (2022) in Cameroon, BAMBA et al. (2013), SOMA et al. (2021) and TINDANO et al. (2024) in Burkina Faso, and SENE et al. (2019) in south-eastern Senegal. Other authors such as MAÏGA et al. (2022) and BOHBOT (2017) have also shown the harmful effects of the large-scale use of chemicals in gold processing.

### III.2. Risk of serious accidents

Rockfalls can cause injuries when fragments of rock fall into holes. Injuries include cuts, lesions and contusions caused by the use of rudimentary mining equipment (picks, axes, etc.), and burns caused by unprotected handling of chemicals. At Loto, gold miners use tree trunks to maintain the vault, which unfortunately, with the action of rain and the effect of dynamite, causes the ground to crumble, leading to accidents. This explains the high response percentages for landslides (89.15%), traumas (78.26%) and drownings (47.2%). According to authors such as LONG et al. (2015), CLARKE et al. (2015), LEONARD et al. (2022) and GABRIEL et al. (2022), these risks are the most lethal and generally occur during the rainy season. Gold miners use the holes/wells for shelter during the rainy season, leading to cases of drowning. Also, because the holes at Loto site are up to 100 metres deep, some gold miners are caught out by the rains and have no time to get out. These cases were observed by CLARK et al. (2015) and LONG et al. (2015) in Ghana in their studies respectively on the risk factors of gold panning and on the injuries caused by this activity.

### III.3. Risk of illness

Observations in the field have shown that gold washers sometimes remain in unsanitary water for long periods. At Loto, zones dedicated to gold processing are marked out on both sides. At the stone-crushing level, women with their children in their arms inhale the dust they produce, as well as that produced by the mills installed for crushing. Also, on both sites, the gold miners live in habitats built of plastic sheeting and in a dusty environment where the food and water they consume are likely to be polluted or contaminated. What's more, they expose themselves to mercury and cyanide when extracting gold. These manipulations, which take place near watercourses, could contaminate the water, which in turn is a source of infection and skin-related

diseases. In addition, malaria is favoured by living conditions (precarious housing, promiscuity) and non-compliance with chemoprevention treatments (malaria). Respiratory and digestive problems are respectively linked to the dust generated by artisanal gold mining and the unhealthy food consumed. Respondents also noted the presence of sex workers on both sites, who sometimes accept clients when they offer a large sum of money in exchange for unprotected sex. This leads to the proliferation of sexually transmitted infections and sexually transmitted diseases (STIs/STIs), notably HIV/AIDS, and unwanted pregnancies. These findings are similar to those of KALAKUKO et al. (2017) in eastern Democratic Republic of Congo. Furthermore, according to the IOM (2021), exposure to health risks depends on living conditions, working conditions, the environment and behaviour. Thus, the characteristics of individuals and spaces are likely to weaken the health of populations and make them vulnerable to health risks (IOM, 2021, GABRIEL et al., 2022). Consequently, the IOM designates women, children and migrants working in the artisanal gold mining sector as particularly vulnerable.

### III.4. Perception of the risks associated with gold panning

Analysis of the perceived risks of artisanal gold mining shows that not only the socio-economic characteristics of gold miners, but also certain variables linked to the practice of artisanal gold mining influence risk perception (tables III and IV). Indeed, artisanal gold miners who educated are more likely to perceive the risks of artisanal gold mining. This can be explained by the fact that education has an effect on access to risk information, and thus increases the ability of artisanal miners to discuss the risks of artisanal gold mining with other actors. Indeed, educated gold miners are very receptive to awareness-raising and will tend to seek out information on the risks associated with this activity. They also tend to develop individual and collective protection measures on the sites. In addition, this category of people acts as a relay in raising awareness among other gold miners. SANGLI et al. (2022) demonstrated in their study that education, experience, unemployment and gender are variables that impact on the perception of the risk of artisanal gold mining on human and environmental health. Gold miners with high incomes are likely to have low perceptions of the risks of artisanal gold mining, in contrast to those with low incomes. This can be explained by the fact that income is a predictor of low-risk perception among gold miners. Indeed, gold miners and mining communities tolerate the high risks of artisanal gold mining while

maximizing the financial benefits to sustain their livelihoods. These findings are similar to those of ARMAH et al. (2020) in Ghana in their study of the effect of mercury on health and those of DAGARU et al. (2009) in their study of water quality in artisanal gold mining in Romania. However, MAHMOUD et al (2020), in their study of the determinants of perceived risk among gold miners in Sudan, found no significant link between income and perceived risk. The number of years of experience in artisanal gold mining would influence perceived risks. Indeed, as a general rule, the number of years spent working in a field enables people to accumulate more knowledge about the risks of the field. However, according to MAHMOUD et al. (2020), the number of years spent working in artisanal gold mining has a negative influence on the perception of artisanal gold mining risks. Indeed, according to these authors, workers with a high number of years working in artisanal gold mining are likely to perceive a sense of control over the risks of artisanal gold mining practice, hence the minimization of negative consequences. They therefore tend to underestimate the risks. This is what MAHMOUD et al. (2020) call "perceived personal invulnerability to risk". As for the occupation variable, gold miners employed in sinking (digging) perceive the risks of artisanal gold mining more than others, and this can be explained by the fact that most causes of injury are related to sinking. These injuries sometimes result in the loss of body parts such as toes, fingers, feet, etc. These results are similar to those of CLARKE et al. (2015) in their study of gold miners' injuries in Ghana and those of LONG et al. (2015) in their study of injury risk factors in artisanal gold mining in Eastern Ghana. The many accidents that occur on artisanal gold mining sites are generally echoed by other gold miners. Indeed, it's very common for a goldminer to hear, witness or even know of another goldminer who has suffered injury, illness, died or given up artisanal gold mining as a result of serious accidents. This information sometimes creates a feeling of fear of being a victim. In the context of our study, the model shows that gold miners who have been sensitized to the risks of gold panning are likely to perceive the risks of artisanal gold mining, and this indicates that the information transmitted through sensitization sessions appears to be very important in creating and shaping perceived risk. These awareness-raising events, generally held in "easy" French and local languages, reach a large number of people. This could be an effective means of communication to raise awareness of the harmful effects of artisanal gold mining. These results corroborate those of MAHMOUD et al. (2020) on artisanal gold mining in Sudan, and ARMAH et al. (2020) in Ghana. Compared to the

period prior to the establishment of artisanal gold mining sites, the people surveyed felt that, overall, water sources were of fairly good quality. The use of chemicals to extract gold is probably responsible for the reduction in the quality of water sources. In Burkina Faso, mercury destined for gold-panning sites was spilled into the Mouhoun river, causing the death of fish and livestock. These results are in line with those of ARMAH et al. (2020) in Ghana, in their study of the effect of mercury use on health, as well as those of DAGARU et al. (2009) in their study of water quality in artisanal gold mining in Romania and MAHMOUD et al. (2020) in Sudan.

## Conclusion

The study identified ecological and health risks, and analysed perceptions of the risks associated with artisanal gold mining. Analyses of survey results show that gold miners are exposed to risks of trauma, rockfall, drowning and accidents that can cause death. In addition, logistic regression analysis shows that the variables education, income, motivations, awareness, occupations are more likely to predict perception of the risks of artisanal gold mining. Based on the main findings of the study, we recommend that the authorities:

- list and identify all gold miners in the commune;
- continue awareness-raising sessions for artisanal miners on the risks associated with artisanal gold mining;
- set up a system for collecting communal taxes at gold panning sites, so that this activity contributes to the commune's socio-economic development;
- set up a vocational training program to support gold miners wishing to retrain. Mining resources are not inexhaustible;
- strengthen conflict management mechanisms to reduce the environmental and human impact of artisanal gold mining.

## Disclosure statement

The authors declare that there is no conflict of interest.

## Authors' contributions

Y. D. conducted the fieldwork, data analysis and drafting of the manuscript. A. M. D. M. contributed to the discussion, writing and translation into English. I. K. contributed to the discussion and drafting of the manuscript. M. H. contributed by validating the study methodology and supervising the work.

## References

ADRIANA E., HELLER K., STRONGMAN J., HINTON J., LAHIRI-DUTT KUNTALA, MUTEMERI N., 2012. Gender Dimensions of Artisanal and Small-Scale Mining: A Rapid Assessment Toolkit. World Bank, Washington D.C. https://openknowledge.worldbank.org/handle/10986/2731.

AITKIN, M. A., FRANCIS, B., AND HINDE, J., 2005. Statistical Modelling in GLIM 4, Vol. 32. Oxford, UK: Oxford University Press.

ARMAH F, BOAMAH S, QUANSAH R, OBIRI S AND LUGINAAH I., 2016. Unsafe Occupational Health Behaviours: Understanding Mercury-Related Environmental Health Risks to Artisanal Gold Miners in Ghana. Front. Environ. Science 4 :29. https://doi.org/10.3389/fenvs.2016.00029.

BAMBA O., PELEDE S., SAKO A., KAGAMBEGA N. et MININGOU M. Y. W., 2013. Impact de l'artisanat minier sur les sols d'un environnement agricole aménagé au Burkina Faso. https://www.researchgate.net/publication/272229121.

BOHBOT J., 2017. « L'orpaillage au Burkina Faso : une aubaine économique pour les populations, aux conséquences sociales et environnementales mal maîtrisées » in EchoGéo, n°42, pp 1-19 DOI : https://doi.org/10.4000/echogeo.15150.

CLARKE E. E. and KYEREMATENG-AMOAH E., 2015. Injuries among Artisanal and Small-Scale Gold Miners in Ghana. Int. J. Environ. Res. Public Health2015, 12, 10886-10896; doi:10.3390/ijerph120910886. https://doi.org/10.3390/ijerph120910886.

DAGARU D., ZOBRIST J., BALTEANU D., POPESCU C., SIMA M., AMINI M., YANG H., 2009. Community Perception of Water Quality in a Mining-Affected Area. A Case Study for the Certej Catchment in the Apuseni Mountains in Romania. Environmental Management (2009) 43 :1131–1145. http://DOI.org/10.1007/s00267-008-9245-9.

ELHASSAN, M.M.O., MALIK, M.R., MAHGOUB, A.S., KHOGALI, H.S., ELMAGBOUL, B., ELFADIL, T., OKOUED, S., ELTAHIR, K., 2014. Combating yellow fever outbreak in Darfur States.

ELIAS C., DEBORAH SK T., DEBORAH D., MARK D., SOSPATRO E. N. AND KONJE E., 2013. A cross-sectional survey on knowledge and perceptions of health risks associated with arsenic and mercury

contamination from artisanal gold mining in Tanzania. BMC Public Health 2013, 13 :74 http://www.biomedcentral.com/1471-2458/13/74.

FAO, 2021. Burkina Faso, Mali et Niger – Analyse des conflits liés aux ressources naturelles dans les trois pays du Liptako-Gourma : Note de synthèse. Rome. https://doi.org/10.4060/cb7446fr.

FONTES J., & GUINKO S., (1995). Carte de végétation et de l'occupation d'un sol du Burkina Faso : notice explicative (French) [Vegetation and land use map of Burkina Faso : Explanatory note]. *Université de Ouagadougou. Ministère de la coopération française, Projet Campus*, *67*, 881-3101.

GRÂTZ T., 2004. Les frontières de l'orpaillage en Afrique occidentale. Presses de Sciences Po | « Autre part » 2004/2 n° 30 | p 135-150. ISSN 1278-3986 ISBN 9782200920059. DOI : https://doi.org/10.3917/autr.030.0135.

HUNTER M., 2022. Par-delà le sang Or, conflits et criminalité en Afrique de l'Ouest. 61p.

IGF, 2017. Guide IGF à l'intention des gouvernements : Gérer l'activité minière artisanale et à petite échelle. Winnipeg: IIDD. https://www.iisd.org/system/files/publications/igf-guidance-for-governments-asm-fr.pdf.

INSD, 2017. Enquête Nationale du secteur de l'orpaillage. Burkina Faso, Institut Nationale de la Statistique et de la Démographie. https://www.insd.bf/sites/default/files/2021-12/Principaux_Resultats_ENSO.pdf. 9p.

IOM, 2019. Les fièvres aurifères au sud –Est du Sénég*al.* Analyse des profils et dynamiques migratoires dans la région de Kédougou. Résumé de recherche. 2p.

IOM, 2021. Risques, vulnérabilités et besoins sanitaires des migrants et des communautés des villages aurifères de Kédougou. OIM, Sénég*al.* ISBN 978-92-9268-430-3.

KALAKUKO K., MASILYA M., ATUMISHI MUBANGU E. K., LUNDIMU E., MUCESO J., LWAKI K., KYETILE H. AND ISUMBISHO M., 2017. Perceptions des orpailleurs et de la population sur les effets environnementaux et socio-sanitaires de l'exploitation de l'or à Kamituga, dans l'Est de la RDC. International Journal of Innovation and Scientific Research ISSN 2351-8014 Vol. 29 No. 1 Feb. 2017, pp. 78-86.

LEONARD L. TAMPUSHI, ONYARI J. M., MUTHAMA N. J., 2022. Assessing Social and Environmental Impacts of Artisanal and Small-Scale Gold Mining Practices in Lolgorian, Kenya. European Journal of Sustainable Development Research 2022, 6(3), em0192 e-ISSN: 2542-4742. 16p.

LONG N., KAN S. AND NEITZEL R. L., 2015. Injury Risk Factors in a Small-Scale Gold Mining Community in Ghana's Upper East Region. Int. J. Environ. Res. Public Health 2015, 12, 8744-8761; doi :10.3390/ijerph120808744 https://doi.org/10.3390/ijerph120808744.

MAHMOUD A. F., PALA I., CW HOEB V., 2020. Determinants of perceived risk among artisanal gold miners: A case study of Berber locality, Sudan. The extractive industries and society 7 (2020) 748-757. https://doi.org/10.1016/j.exis.2020.03.006.

MARCON A., NGUYEN G., RAVA M., BRAGGION M., GRASSI M., ZANOLIN M. E., 2015. A score for measuring health risk perception in environmental surveys in Italya. Science of the Total Environment 527–528 (2015) 270–278. http://dx.doi.org/10.1016/j.scitotenv.2015.04.110.

MEGRET Q. and CROS M., 2018. L'or, le sang, la pluie et les génies : Chroniques ethnographiques d'un conflit entre orpailleurs et autochtones lobi du Sud-Ouest burkinabè. Publié aux éditions « Afrique contemporaine » 2018/3 N° 267-268. ISSN 0002-0478 ISBN 9782807391741. https://www.cairn.info/revue-afrique-contemporaine-2018-3-page-113.htm.

N'DIAYE K., 2020. Le développement de l'orpaillage, son impact environnemental et sanitaire dans le sud-est du Sénégal : exemple du site aurifère de Bantako. Mémoire de Master de l'Université de Liège. 82p.

OUMAR M. O., TCHOBSALA, MEGUENI Cl., BELLO M., SALI B., PA AI V. N., 2022. Evolution du couvert végétal dans les sites d'exploitation artisanale de l'or des aires protégées du département de Mayo-Rey. International Multilingual Journal of Science and Technology (IMJST) ISSN: 2528-9810 Vol. 7 Issue 8, August – 2022.

REA L.M. 1997. Calcul de la taille d'un échantillon pour une enquête. Fiches techniques et méthodologiques. P713-716.

REICHEL V., 2018. Commerce illicite de l'or artisanal en Afrique subsaharienne. Article publié dans Annales des Mines - Réalités

industrielles 2018/4 (Novembre 2018), pages 35 à 39 Éditions Institut Mines-Télécom ISSN 1148-7941 DOI10.3917/rindu1.184.0035.

RICHARD M., MOHER P., ET HAMZA, D., 2015. La santé dans l'exploitation minière artisanale : Un manuel pour instructeurs, Artisanal Gold Council, Victoria, BC. ISBN : 978-0-9939459-3-9. 79 p.

ROUAMBA J., 2014. Risques environnementaux et sanitaires sur les sites d'orpaillage au Burkina Faso : cycle de vie des principaux polluants et perceptions des orpailleurs (cas du site zougnazagmligne dans la commune rurale de Bouroum, région du centre-nord). Mémoire de fin d'étude de Master. 101p.

SANGLI G., OUATTARA B., AZIANU K. A., OUEDRAOGO M., 2022. Femmes et fréquentation des sites d'orpaillage au Burkina Faso : un aperçu des perceptions de la communauté. Revue Internationale Donni, 2022, 02 (02), pp.249-257. ffhal-04319808. https://h*al*.science/hal-04319808.

SOMA A, COMPAORE N. ET YAMEOGO L., 2021. Orpaillage, mutations environnementales et risques sanitaires dans le sous-bassin versant du fleuve Mouhoun au Burkina Faso. 14p. Revue Espace Territoires Sociétés et Santé (retssa-ci.com).

TIMOTHY L., EDWARDS R., YUSUF S., SPARMAN C., 2023. Assessing the economics and finances of Artisanal and small-scale gold mining in Guyana. Journal of rural study 97 (2023) 438-448. 11p.

TINDANO E., GANAME M., BONGOUNGOU S., BAYEN P., 2024. Effect of artisanal gold mining on woody plant diversity in Western Burkina Faso. https://doi.org/10.1016/j.sciaf.2024.e02221.

TOMICIC, C., VERNEZ, D., BELEM, T., BERODE, M., 2011. Human mercury exposure associated with small-scale gold mining in Burkina Faso. International Archives of Occupational and Environmental Health, 84(5) :539-546, 2011. 14p.

TUFFERYP S., 2017. Modélisation prédictive et apprentissage statistique avec R. Edition Technip, Paris, 2017. ISBN 978-2-7108-1178-7. 405 p.

TYCHSEN, J. & CHARLES, N. (EDS), 2019. La mine artisanale en Afrique de l'Ouest francophone. Service géologique du Danemark et du Groenland (GEUS) - Copenhague/Danemark et Service géologique de la France (BRGM) - Orléans/France, 300 p.

UNEP, 2012. Submitted to the 11th Session of the United Nations Permanent Forum on Indigenous Issues (UNPFII) 7 – 18 May 2012, United Nations, New York.

WADI, E. and ALREDAISY, S., 2015. Socioeconomic and environmental implications of traditional gold mining in Sudan: the case of Barber locality. River Nile State. Am. Based Res. J. 4, 1–11.

WHO, 2017. Risques pour la santé au travail et l'environnement associés à l'extraction minière artisanale et à petite échelle de l'or. Environmental and occupational health hazards associated with artisanal and small-scale gold mining. Genève. Licence : CC BY-NC-SA 3.0 IGO.