

Prevalence of Pulmonary Tuberculosis among Artisanal Miners and the Peri-Mining Community in the Province of Lualaba in the Democratic Republic of Congo

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Abstract

Background: The magnitude of TB in DRC has been very high, and it is one of the high burden countries that account for more than eighty percent of the global TB burden. Artisanal miners have a disproportionately high risk of contracting tuberculosis for several reasons related to their professional exposure and other socio-economic factors. Hence, the objective of this study was to assess the prevalence of TB in the miners and peri-mining communities. **Methods:** The study applied a cross-sectional study conducted in Lualaba province, recruiting respondents from the two study groups. All individuals who gave written consent to participate in the study were interviewed, and sputum samples were collected for GeneXpert testing. **Results:** A total of 1778 study participants were included, composed of 889 each from both groups of the study population. A significant majority were males. The combined prevalence of tuberculosis for the two studied subpopulations was 4.1%. Based on the disaggregated analysis, the prevalence was 5.2% among the miners and 3.0% among the peri-mining community. The difference was statistically significant, with a P-value of 0.023. **Conclusion:** This study found that the prevalence of TB in mining communities was very high, which was twice as high compared to the peri-mining community. Mining is one of the fastest-growing sectors in the province, and the risks of TB transmission and its impact on the community could, therefore, be even greater. Tailored programmatic interventions

are needed, including targeted TB screening, contact tracing, and routine testing of all mine workers.

Keywords

Mycobacterium Tuberculosis, Prevalence, Characteristics

1. Background

According to the global TB report, 10.6 million people were estimated to have tuberculosis in 2022, an increase of 4.5% compared to 2021, and 1.1 million people died from TB (including 187,000 among HIV-positive people). The burden of drug-resistant TB also increased by 3.3% in 2022. In that same year, the estimated TB incidence in the Democratic Republic of Congo (DRC) was 334,000, of which the country notified 260,515 TB cases [1]. A recent report showed that the prevalence of tuberculosis among gold miners in South Africa was three times higher than that of the general population. On the other hand, some countries have reported a prevalence of tuberculosis among miners eight to ten times higher than the rest of the community [2] [3].

Artisanal miners have a relatively high risk of contracting tuberculosis for several reasons: overcrowding, poor ventilation of housing in mining camps as well as the mining sites, significant exposure to silica or mining dust containing microparticles of coal, HIV/TB co-infection, exposure to alcohol, drugs and the sex industry with peri-mining communities, and, in some cases, poor diet [4]-[10].

Transmission of tuberculosis increases in a poorly ventilated, dark, and humid environment, as is the case in most artisanal mining shafts. Because miners have a high prevalence of TB, they also pose a high risk to the surrounding communities they come into contact with. Noting the high prevalence of TB in the mining sector and its associated negative effects on surrounding communities, the Heads of State of the Southern African Development Community (SADC) region developed the “Declaration on Tuberculosis in the Mining Sector in Southern Africa” in 2012 [2] [11] [12].

The declaration highlights, in particular, the strong contribution of the mining sector and miners to the economy and development of the nations of the region, but also the considerable negative effects on the health of miners and their families [11] [12].

The Democratic Republic of Congo (DRC) has been committed to the fight against tuberculosis for several years through its National TB Control Program (NTCP). The initiative has been making progress for several years in ending the epidemic, as recommended by the Global End TB Strategy [1].

However, some mining provinces in the DRC continue to have a high prevalence of tuberculosis of all forms. Lualaba, which has reported an increasing number of TB cases over the past three years (5,947 in 2020, 6,387 in 2021, and 7,287

in 2022), is a mining province with artisanal mining quarries scattered throughout a large number of health zones (HZs). Poor working conditions expose miners to respiratory diseases, including TB. A considerable number of TB patients are reported each year. The rate of increase is disproportionate within this vulnerable population, for which reports showed an increase of more than 45% in TB notification between 2020 and 2022 (428 in 2020 and 623 in 2022). The nomadic nature of this specific population makes treatment difficult and results in most cases with unfavourable treatment outcomes (including clients lost to follow-up) [13]-[18].

Hence, the objective of the study is to assess the prevalence of TB among miners and peri-mining communities in the Lualaba Health Zones (ZS) in the DRC. The goal is to make quality health services available, accessible, and acceptable, especially for vulnerable and underserved target populations. Lualaba is one of the mining provinces reporting a high number of TB cases, with a total of 623 cases of TB among miners during the year 2022.

2. Materials and Methods

2.1. Type of Study

This is a cross-sectional study with an analytical purpose.

2.2. Study Sites

Lualaba province was selected by the National Tuberculosis Control Programme on the basis of a combination of criteria, including TB incidence and safety in this specific population.

This province includes a Provincial Coordination for the Fight against Tuberculosis (CPLT), which operates with 13 health zones in accordance with its geographical coverage, including the ZS of Manika, Kanzenze, Dilala, Lualaba and Fungurume, which include the 15 study sites. The table shows the distribution of artisanal mining quarries (AMCs) in these five SAs.

2.3. Data Collection

Data collection was preceded by training of national supervisors and then of interviewers at the provincial level.

2.3.1. Study Participants

The survey used a quantitative approach and targeted two groups of respondents:

- Miners in artisanal mining quarries.
- Members of peri-mining communities.

2.3.2. Sample Size

There are very few studies on risk factors for TB among minors in the DRC. However, a recent study in Tanzania showed that about 7% of miners had tuberculosis [19]. Thus, to estimate the sample size, detect the proportion of the study population, determine the prevalence of tuberculosis, and identify the risk factors related to TB in this population in the DRC, we applied the following formula:

$$n = kt^2 \frac{P(1-P)}{e^2}$$

To calculate the sample size of minors with tuberculosis, it is necessary to take into account the following factors: the desired level of confidence in the survey results (S), the acceptable margin of error for the survey results (e), the effect of the sampling design (k) and the estimated initial levels of the indicators to be measured (p).

In concrete terms, n = sample size; S = 95%, then $t = 1.96$ “study of acceptable accuracy”; p is the proportion of miners suffering from tuberculosis on (0.07).

Then, $n = 2 \times 1.96^2 \times 0.07 (1 - 0.07)/0.04^2 = 319$ per ZS, which we increase to 320 per ZS. In consideration of the non-response rate and for fear of falling to a minimum size, we added 15% of non-respondents. The sample size was increased to 367, which was rounded to 370 for each of the five target ZS of the study. The minimum size was 1600 people which was divided between the respondents and the 15 study sites.

2.3.3. Sampling Procedure

Choice of Statistical Units of Study

1) Choice of primary units (1st degree):

- On the basis of the list of artisanal miners’ associations of the CPLT of Lualaba that are accessible from a security and geographical point of view, 15 artisanal mines were selected.

2) Choice of artisanal miners (2nd degree):

- 59 artisanal miners per site were randomly selected in a simple manner, based on the exhaustive list of artisanal mining personnel of the selected mine, and were interviewed.
- 59 members of the peri-mining community per site were randomly selected in a simple manner based on the exhaustive list of households in the neighborhood where the mine was located.

Interviews were conducted with miners and members of the peri-mining community selected from the artisanal mines of Lualaba.

The inclusion criteria for study participants were: for miners, those who have at least one year’s service as a miner, be involved in the mine’s activities on a daily basis, consent to the study, and be able to participate. Whereas for the peri-mining population, the study included those who reside in the vicinity of one or more artisanal mines (at most 10 km from the mine) and have lived for at least one year in the vicinity. The exclusion criteria were if the respondent was unable or unwilling to give consent and adult members of the peri-mining community who have been living near one or more artisanal mines for less than one year and have not given consent to participate in the study.

2.4. Data Collection

The selected artisanal mines and peri-mining community members were con-

tacted by the community relays (RECO). The latter helped the interviewers to find the addresses of households to set the date of the interviews. Interviews were carried out using the questionnaire, and sputum collection was conducted from the selected individuals.

Sputum samples were obtained either spontaneously or induced using a spittoon by the community outreach workers wearing respiratory protection masks to avoid inhaling bacilli [20]. They were then sent to the 4 biological analysis laboratories targeted by the study at the provincial level: Kizito, HPK, LPR, and DI-PETA/Fungurume. GeneXperts was used to confirm cases of tuberculosis and rifampin resistance.

2.5. Data Analyses

The data was encoded in the field on tablets using the Surveycto mobile app. This contained the input mask set up with XLSForm on the basis of the data collection sheet (made with the Sphinx® software). The encoded forms were submitted to the surveyCTO server by the supervisors.

Subsequently, the database was downloaded and submitted for analysis (after quality control and data cleaning). Internal quality control was carried out by the national supervisors and the biostatistician after the submission of the completed questionnaires. Data cleaning allowed for data verification, control, and correction. The audit included identifying inconsistencies, missing data, and data entry errors.

The quantitative data were analyzed with the R® 4.2.4 software, and the results were presented in the form of tables synthesized according to the numbers, frequencies, and associated proportions or in the form of illustrations through maps and graphs. Categorical variables were summarized by their relative frequencies (and 95% confidence intervals), while numerical variables were summarized by appropriate measures of central tendency. Median comparisons were performed using the Wilcoxon test, while proportions were compared using the exact Fisher test. In addition, for comparisons and associations between the dependent variable “respondent status” and the other variables, the Pearson Chi² test or the exact Fisher test was used.

In addition, a multivariate logistic regression was performed with the variable “respondent status” having two modalities (miner and member of the peri-mining community) and the explanatory variables. A general linear regression model (GLM) analysis with a significance level (p) of 5% was performed, and the odds ratios were calculated using their confidence interval. However, several models have been made, and we have retained those with the smallest Akaike indices.

2.6. Ethical Considerations

2.6.1. Ethics Committee Authorization

The study protocol was submitted to the Ethics Committee for approval prior to the start of this research activity. After approval, an information letter was sent to the CPLT of the province of Lualaba (target of the study) to inform them of the

study, including its objectives and methods.

2.6.2. Informed Consent

In accordance with the principle of informed consent, the study on the prevalence and risk factors of tuberculosis will be based on an informed consent form in the local language and French, to ask each respondent to give their consent for the collection and processing of their personal data (after being fully informed of the nature of the study, of the persons involved in it, of the way in which the data is processed, stored and used). Interviewers explained to respondents that they are free to decline the interview, to withdraw from the interview at any time, or to refuse to answer a particular question or set of questions. Interviewers ensured that the respondent had given informed consent based on the informed consent form before starting the interview.

2.6.3. Confidentiality

Confidentiality refers to the right of access to data provided by study participants. The only people allowed to see the list containing the contact and codes of all respondents and the informed consent forms were the interviewers who collected the data and the supervisors. Those responsible for verifying and analyzing the data did not have access to the list that contained the respondents' personal contact information.

In order to ensure the confidentiality of the data, agreements were signed by the research team, investigators, and supervisors.

2.6.4. Advantages of the Study

The interviewers provided participants with information about the care services available in the province. The objective was to inform respondents about the services available to meet their health needs. As a result, all respondents who tested positive for GeneXpert were put on treatment.

The direct benefits of the study include the development of an action plan to support the implementation of programs to improve access to TB diagnosis and management in artisanal mines in DRC. Measuring TB prevalence and identifying TB risk factors among miners and peri-mining communities can contribute to improved screening, expanding universal coverage of tuberculosis preventive treatment (TPT), drug-resistant tuberculosis treatment (DRTB) and drug-susceptible TB (TBPSM), and improving community access to TB services.

2.7. Study Limitations

Participants were asked about their personal information, sensitive behaviors, and exposure to response activities, and such information was probably subject to a social desirability bias and a memorization bias. In addition, participants who agreed to enroll, consent, and participate in the study may be more likely to comply with the terms of enrollment, program retention, and treatment adherence than those who declined to participate.

2.8. Study Timeframe

The data collection was conducted in October and November 2023 in the selected sites located in Lualaba province.

3. Results

3.1. General Information

The study covered 15 mining sites in Lualaba province. These artisanal mining sites represented the majority (86%) of copper and cobalt. A total of 1778 subjects were recruited for the study, with equal representation of both groups of respondents: 889 peri-mining communities and 889 artisanal miners. In terms of gender composition, 1275 (72%) were male and 503 (28%) were female.

3.2. Socio-Demographic Characteristics of the Miners and Peri-Mining Communities Surveyed

As shown in **Table 1**, the median age for the two groups of respondents was similar: 31 (QIS 24.0 - 42.0) years for the peri-mining population (PMN) and 32 (QIS 25.0 - 40.0) years for miners (MN). The most representative age group was 20 - 40 years old for both groups. The two groups (MNP and MN) differ in a number of characteristics, including the gender distribution (37% of women for MNs versus 20% for MNs). The majority, 468 (80.0%) of respondents, had attended an elementary or secondary level education, whereas 17% had never been to school and only 2.5% had a university level degree. Among the peri-mining population, 422 (47.0%) had primary education, while for miners, the figure was 457 (51.0%).

Table 1. Socio-demographic characteristics of the participant mining and peri-mining communities, Lualaba province, DRC, November 2023.

Characteristics	Total n = 1,778 ¹	Community n = 889 ¹	Miners n = 889 ¹	P-Value ²
Age	32 (24,41)	31 (24,42)	32 (25,40)	0.8
Age group				<0.001
<20 years	252 (14%)	152 (17%)	100 (10%)	
20 - 40 years old	1,059 (60%)	485 (55%)	574 (65%)	
>40 years	467 (26%)	252 (28%)	215 (24%)	
Sex				<0.0001
Female	503 (28%)	326 (37%)	117 (20%)	
Male	1,275 (72%)	563 (63%)	712 (80%)	
Educational level				0.010
No formal training	310 (17%)	148 (17%)		
Primary	879 (49%)	422 (47%)		
Secondary	544 (31%)			
College	45 (2.5%)			

¹n: Median (IQR). ²Pearson's Chi-squared test; Wilcoxon rank sum test; Fischer's exact test.

As shown in **Table 2**, a total of 73 individuals were found to be positive by GeneXpert testing using sputum samples, which gives rise to a combined prevalence of tuberculosis for the two studied subpopulations of 4,1%. With further disaggregation by the type of respondent, the prevalence was 5.2% for MNs compared to 3.0% for the peri-mining community. The difference was statistically significant, with a P-value of 0.023.

Table 2. Results of GeneXpert analysis of the participants' mining and peri-mining communities surveyed, Lualaba province, DRC, November 2023.

Characteristics	Total n = 1,778 ¹	Community n = 889 ¹	Miners n = 889 ¹	P-Value ²
GeneXpert				0.023
Positive	73 (4.1%)	27 (3.0%)	46 (5.2%)	
Negative	1,705 (95.9%)	862 (97.0%)	843 (94.8%)	
Rifampicin Resistance				>0.9
Yes	1 (<0.1%)	0 (0%)	1 (0.1%)	
No	1,777 (99.9%)	889 (100%)	888 (99.9%)	

¹n: Median (IQR). ²Pearson's Chi-squared test; Wilcoxon rank sum test; Fischer's exact test.

As shown in **Figure 1**, GeneXpert's positivity rate by sex showed that 22 of the females and 52 of the male participants were positive for the test.

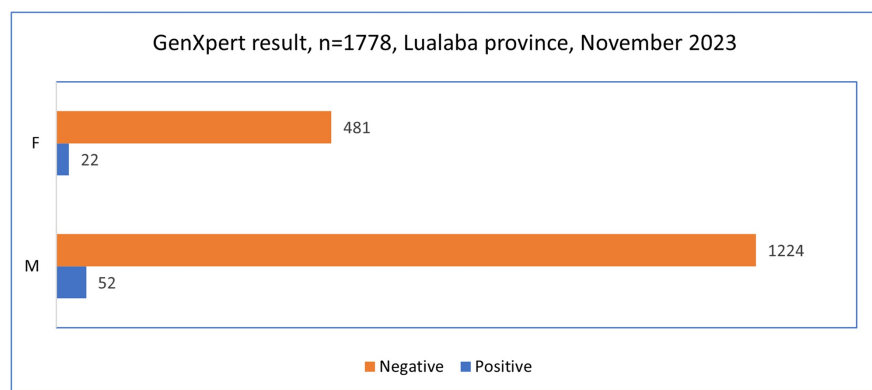


Figure 1. Results of GeneXpert testing of mining and peri-mining communities surveyed by sex, Lualaba province, DRC, November 2023.

4. Discussion

The overall prevalence rate of TB in the study area was 4,100/100,000 (4.1%), 13 times higher than the national prevalence of the Democratic Republic of the Congo, which is 317 per 100,000 population [1]. This could be attributed to a large extent to the socio-economic factors in the mining sector related to poor ventilation of mines in Lualaba province and the lack of routine TB screening among all mine workers, which facilitates the continued transmission of TB in mining sites.

It is widely reported that more men than women suffer from tuberculosis. This could also explain the high prevalence of tuberculosis among men in the present

study, with nearly 70% of the subjects male compared to 30% of women.

Regarding the prevalence of tuberculosis for the two studied subpopulations, *i.e.*, MNPs and MNs, a prevalence of 5.2% for MNs compared to 3.0% for the peri-mining community was observed, *i.e.*, a prevalence almost twice as high among MNs compared to MNPs. This figure is much lower than what is reported in miners in other studies, namely about six times the prevalence of TB in miners than in the general population [21] [22]. Overall, the results of the current study show that the burden of TB is very high among underground miners and the communities around them. In addition, the burden is greater among underground miners because the majority live in quarries or in peri-mining areas with poor housing conditions (huts with small windows), resulting in poor ventilation and a lack of light. This constitutes a double exposure to tuberculosis for this subpopulation. All these risk factors explain the high exposure of the artisanal miner subpopulation compared to the general population.

Similarly, secondary data analyses of NTP program data in Ghana showed the high prevalence of TB in the artisanal mining communities and in miners, which was more than four times higher than the general population. The finding reinforced the need to target these populations with outreach programs and highlighted the diagnostic value of cough, which demonstrates the usefulness of clinical symptom screening in this population that may be harnessed even in the absence of X-ray [23].

According to a multivariate regression that was conducted to estimate the contribution of mining activity to TB incidence and prevalence in Sub-Saharan Africa, the study found that mining production was associated with higher population TB incidence rates (adjusted $b = 0.093$; 95% confidence interval [CI] = 0.067, 0.120; with an increase of mining production of 1 SD corresponding to about 33% higher TB incidence or 760 000 more incident cases) after adjustment for economic and population controls [24].

A cross-sectional study of migrant miners in Mozambique reported a TB prevalence of approximately 0.3% [25]. But, many Mozambican miners migrate and work in South Africa, where there is a well-developed and established health network that includes routine TB screening among miners, which could help reduce TB prevalence. These TB prevention interventions involve health education, awareness-raising, screening, and investigation of TB among mine workers. Indeed, in other countries such as South Africa, health authorities have implemented a “contact tracing and investigation approach”. Thus, when a miner is infected with tuberculosis, the mining pit and the group of miners from which the patient comes are targeted with the help of health services in the fight against tuberculosis. Through this approach, miners have benefited from health services that have led to a reduction in TB among these vulnerable populations. Unfortunately, there is no such program targeting the community living around the mines in Lualaba province. Having TB strategies in place in these communities is of paramount importance if we are to achieve TB goals.

5. Conclusions

The aim of this study was to contribute to the improvement of the fight against tuberculosis in the DRC through the measurement and determination of risk factors related to TB among artisanal miners and the peri-mining community in Lu-alaba.

The study successfully achieved its objective, and the results will contribute significantly to providing an up-to-date overview of tuberculosis in artisanal mining. It will also provide important recommendations to the government and other stakeholders on efforts to end the TB epidemic in the country as part of global efforts to eradicate TB by 2035.

This study found that the prevalence of TB in mining communities was very high (13 times higher compared to the national prevalence), but more specifically, it showed that the prevalence of TB among miners was twice as high compared to the peri-mining community. Mining is one of the fastest-growing sectors in Lu-alaba province; therefore, the risks of TB transmission and its impact on the community could be even greater. This means moving beyond the traditional approach and implementing the new approach of targeted screening of miners and conducting contact tracing and active testing of all mine workers of the index case. If we are to achieve global TB targets, we need to redouble our efforts in this area and in similar communities where the burden of disease is relatively high. Further studies are needed in other mining provinces in the DRC to assess the determinants of such a disease burden in mining communities, including the dynamics of TB transmission.

6. Recommendations

The main results obtained in this study have led to the formulation of operational recommendations aimed at reducing the prevalence of tuberculosis among the mining population and contributing to the goal of eradicating TB by 2035.

6.1. Suggestions to Health Facility

- Behavioral change and communication to improve the behavior of mine workers.
- Encouraging the use of personal protective equipment.
- Improve the TB patient management strategy in mining settings by integrating contact tracing, follow-up, and active monitoring of treatment.

6.2. Suggestions to the NTP

- Train healthcare providers on contact tracing strategy.
- Integrate the Community contact tracing package into the various CDTs.
- Strengthen awareness and organize voluntary screening in mining environments.
- Increase awareness-raising to enable community workers in SZs to minimize exposure of mining communities to risk factors for TB transmission.

- Replicate the study to other mining provinces in order to elucidate the problem of factors associated with tuberculosis among miners in the DRC.

6.3. Suggestions to Partners

Support the NTP and the government in the implementation of the recommendations from this study in order to achieve the goal of eliminating TB in the DRC by 2030.

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Availability of Data and Materials

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Authors' Contributions

ES, SM, and BD conceived the study and prepared the protocol, coordinated data collection, conducted data analysis, and drafted manuscripts. HW, YT, SM, FE, and FK provided technical support with the preparation of the proposal and the interpretation of data, advising on participating in data analysis and critically reviewing the manuscript. They supported the preparation of protocol, coordinated fieldwork, and supported data analysis and interpretation. SM and FE coordinated data entry and analysis. All authors read and approved the final manuscript. All authors participated in the critical appraisal and revision of the manuscript.

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List of Abbreviations and Acronyms

CDT	Diagnostic and Treatment Center
CPLT	Provincial Coordination for the Control of Tuberculosis
EDEN SANTÉ	Education, Environment, and Health
NTP	National Tuberculosis Control Program
OSWAP	Africa Health Bridge
WHO	World Health Organization
DRC	Democratic Republic of Congo
TB	Tuberculosis
DR TB	Drug-resistant tuberculosis
TPT	Tuberculosis Preventive Treatment
ZS	Health Zone

Conflicts of Interest

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

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