

Review

Occupational Health Risks and HIV Prevention Programming for Informal Extractive Miners in Sub-Saharan Africa: A Narrative Review of Interventions, Challenges, and Lessons Learned

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Abstract: Introduction: The objective of this narrative review is to examine the health risks associated with informal mining in Sub-Saharan Africa (SSA), with a particular focus on HIV prevention. It aims to review existing interventions targeting this population and identify challenges and opportunities for improvement. **Methods:** A comprehensive literature review was conducted using databases such as Google Scholar, PubMed, ScienceDirect, and Cochrane Library. Studies and reports published between 2000 and 2023 that focused on occupational health risks and HIV prevention interventions in the informal mining sector of SSA were included in the analysis. **Results:** Informal mining in SSA presents significant health risks to workers, including exposure to hazardous substances, poor working conditions, and limited access to healthcare. These factors, combined with the high prevalence of HIV/AIDS in the region, make informal miners particularly vulnerable to infection. The review identified several key themes related to occupational health risks, such as poor environmental and sanitation conditions, increased vulnerability due to factors like poverty and lack of education, and limited access to healthcare services. A variety of interventions have been implemented to address HIV prevention among informal miners in SSA. These include behavioral strategies like peer education and social marketing campaigns, as well as biomedical interventions such as counseling, testing, and pre-exposure prophylaxis (PrEP). However, challenges persist in delivering effective HIV prevention services to this population. These challenges include restricted access to healthcare, the high mobility of miners, limited resources, and stigma associated with HIV. **Conclusions:** The findings of this review highlight the urgent need for integrated health services and tailored interventions that address the specific issues faced by informal miners in SSA. Community-based and culturally sensitive programs, developed in collaboration with mining communities, are essential for effective HIV prevention. Future research should evaluate the long-term impact of interventions and explore their scalability. To improve intervention effectiveness and sustainability, stakeholders should focus on community engagement, strengthening health systems, and addressing structural barriers. A multi-sectoral approach is necessary to tackle the broader determinants of health in mining communities.

Keywords: HIV prevention programming; informal extractive miners; narrative review; occupational health risks; Sub-Saharan Africa

1. Introduction

Millions in Sub-Saharan Africa rely on informal extractive mining for their livelihoods, making it a crucial economic driver for the region [1]. However, these miners, often working in unregulated environments with limited safety measures, face significant health risks [2]. Informal mining refers to localized activities focused on exploring and extracting minerals, including precious and base metals. It encompasses a range of processes such as digging, marking, panning, and shoveling that facilitate mineral extraction. The term “informal” indicates that these activities are conducted by individuals, groups, or cooperatives without adherence to formal regulations, and in some cases, they may be carried out illegally. This distinguishes informal mining, often referred to as artisanal or small-scale mining, from formal mining, which involves capital-intensive operations typically managed by large state or multinational corporations. A scoping review of health studies in the context of artisanal and small-scale mining described disproportionately high prevalence and burden of infectious diseases such as HIV/AIDS, tuberculosis, and respiratory illnesses compared to the general population [2]. The very nature of informal mining, frequently conducted in remote areas with limited access to healthcare, further exacerbates the risk of disease transmission.

Informal mining environments, often characterized by socio-economic instability and poor living conditions, amplify risks of HIV transmission through multiple interconnected pathways. High levels of mobility and transient settlements associated with mining lead to increased interaction with local populations, including sex workers, often in settings with inadequate health infrastructure. Studies suggest that informal mining hubs frequently become hotspots for risky sexual behaviors, exacerbated by economic disparities and limited access to education on HIV prevention [2]. Furthermore, the prevalence of informal labor structures means miners rarely have access to employer-supported healthcare or HIV prevention programs, further compounding their vulnerability. These dynamics, when combined with the stigma surrounding HIV in many communities, allow for the perpetuation of the epidemic within and beyond mining communities.

Sub-Saharan Africa remains at the epicenter of the global HIV epidemic, reflecting significant public health challenges and highlighting the urgent need for targeted interventions. As of 2021, the region accounted for approximately 67% of the global population living with HIV, with key populations and their partners disproportionately affected, contributing to over half of new infections. This high prevalence underscores the complex interplay of socio-economic factors, mobility, and limited access to healthcare services that characterize the region. Efforts to address these challenges are ongoing, with key strategies including the scaling up of antiretroviral therapy and pre-exposure prophylaxis, which have shown promise in reducing the risk of HIV transmission. However, persistent barriers such as stigma, discrimination, and the mobility of at-risk populations like informal miners complicate these efforts, necessitating a detailed understanding of both the epidemiological landscape and the social dynamics at play [3].

Over the years, HIV prevention programs in Sub-Saharan Africa have evolved significantly to combat the epidemic, with a particular focus on at-risk populations. Initially centered on awareness-raising and behavioral change, these programs transitioned to evidence-based interventions, including condom distribution and voluntary counselling and testing (VCT). Biomedical interventions such as early antiretroviral therapy (ART) initiation and pre-exposure prophylaxis (PrEP) were also introduced, revolutionizing prevention strategies. Evidence from studies demonstrates the effectiveness of these approaches in reducing HIV transmission rates in the region [4,5]. Community-based initiatives, such as peer education and outreach programs tailored to target communities, have further bolstered prevention efforts, facilitating behavior change and increasing the uptake of preventive measures. Overall, the evolution of HIV prevention programs underscores a comprehensive, evidence-based approach that has contributed significantly to reducing HIV incidence in Sub-Saharan Africa [6,7], marking significant progress towards the global goal of ending the HIV/AIDS epidemic [8].

In particular, implementing HIV programs among informal extractive miners presents distinct challenges. Mining sites' remote and often inaccessible locations present logistical hurdles in delivering healthcare services and implementing preventive interventions. Reaching these dispersed populations with traditional awareness campaigns and service delivery points can be difficult. Additionally, the mobility of mining populations complicates efforts to establish sustainable healthcare infrastructure and maintain continuity of care. Singo et al. highlight the challenges of ensuring consistent condom access and essential healthcare services for informal miners working in geographically isolated communities [9]. Furthermore, the transient nature of the mining workforce can disrupt the continuity of care, particularly for interventions like PrEP, which require ongoing medication adherence. The social stigma surrounding HIV testing and a lack of trust in formal healthcare systems within informal mining communities can further impede program effectiveness, as evidenced by research from Murewanhema et al. [10]. Additionally, the informal nature of mining activities, characterized by irregular income and lack of legal recognition, further marginalizes miners and impedes their engagement with HIV prevention programs [11,12].

Focusing on the high-risk subpopulation of informal miners in SSA is crucial for effective HIV prevention and treatment strategies. This group is often overlooked in public health initiatives despite facing unique and significant risks due to their working and living conditions. Informal miners frequently operate in remote areas with limited access to healthcare services and are exposed to a range of occupational hazards that can exacerbate their vulnerability to HIV. Moreover, the transient nature of their work means that traditional health outreach programs struggle to maintain continuity of care, a critical factor in managing HIV/AIDS. By targeting interventions specifically at informal miners, public health efforts can not only address the direct needs of this population but also mitigate broader public health risks associated with the spread of HIV in these communities. This targeted approach aligns with global health strategies that emphasize the importance of reaching key populations to achieve overall epidemic control, making it not only a necessity but a strategic imperative to focus on informal miners in the region.

This narrative review aims to synthesize existing literature to (1) identify the main occupational health risks for infectious diseases faced by informal extractive miners in Sub-Saharan Africa (SSA), (2) identify the various HIV prevention programs and interventions among informal extractive miners in SSA, and (3) analyze the challenges and lessons learned from implementing HIV prevention programming in the informal extractive mining sector of SSA. This review adds to the body of literature, ultimately contributing to a deeper understanding of effective strategies to promote the health and well-being of this vulnerable population.

2. Methods

A narrative review is a type of literature review that provides a comprehensive summary and synthesis of existing research findings on a particular topic or research question. Unlike systematic reviews, narrative reviews typically do not follow a strict protocol or employ a systematic search strategy [13]. Instead, they rely on the expertise of the authors to identify relevant studies and interpret their findings in a coherent narrative [13]. A narrative review was best for this study, as the research questions were broad and exploratory on a topic with limited and diverse previous research [13,14].

2.1. Defining the Research Questions: The Research Questions for This Narrative Review Were Defined As

- (i) What are the main occupational health risks for infectious diseases faced by informal extractive miners in Sub-Saharan Africa (SSA)?
- (ii) What types of HIV prevention programming and interventions have been conducted among informal extractive miners in SSA
- (iii) What are the challenges and lessons learned from implementing HIV prevention programs in SSA's informal extractive mining sector?

2.2. Literature Search

We conducted a comprehensive search in four databases, Google Scholar, PubMed, ScienceDirect, and Cochrane Library, using a combination of keywords and Boolean operators to capture a wide range of relevant studies. The search terms included “HIV prevention”, “artisanal and small-scale mining”, “informal miners”, “occupational health risks”, and “sub-Saharan Africa”. Searches were limited to studies published between 2000 and 2023 to capture more recent interventions and insights, given the evolving nature of occupational health and HIV prevention. Reference lists of relevant articles were manually screened to identify additional studies.

2.3. Selection of Studies

The selection of studies was based on their relevance and quality, in a process that mirrors that of systematic reviews but enables further flexibility. Due to the limited available research on both occupational health risks for HIV prevention program implementation among informal miners, separate searches were performed for each research question. The inclusion criteria were all types of articles with titles or abstracts indicating a discussion or research on occupational health risk for infectious diseases or HIV prevention programs among informal miners and related terms in English. Grey literature such as technical reports, government documents, conference proceedings, theses, and dissertations not published electronically was used to ensure completeness of details on the information that was retrieved. We excluded articles that did not focus on Sub-Saharan Africa, were not available in full text, or that focused on large-scale mining operations rather than artisanal or small-scale mining activities. This decision was based on the recognition that large-scale mining operations, which are typically formalized, often have established facilities, structured policies, and procedures that support occupational health and HIV prevention. In contrast, informal miners in artisanal and small-scale operations often work under unregulated, high-risk conditions with limited access to health services, making them a distinct and vulnerable population. Furthermore, informal mining differs significantly in its workforce composition, mobility, and socio-economic characteristics, necessitating a focused exploration of their unique challenges and needs.

2.4. Data Extraction and Synthesis

Data extraction of relevant information from the selected studies was guided by a pre-designed data extraction tool developed by the authors. The data extraction tool included tailored elements aligned with each research question. For occupational health risks and infectious diseases, we collected information on population demographics, mining type, health risks identified, and any reported exposure pathways. For HIV prevention programming and interventions, we collected information on program details (e.g., awareness, testing, coverage), implementation strategies, and outcomes. For challenges and lessons learned, we extracted information on implementation barriers, facilitators, and recommendations. This structured data abstraction guided consistent data collection and synthesis across included studies and ensured alignment with the review’s objectives. The analysis involved a manual coding process to summarize, synthesize, and interpret findings from the various sources. First, relevant data were extracted and reviewed for each study, with a focus on answering the research questions. A coding framework was developed inductively, based on recurring themes and patterns that emerged from the data. Key findings were assigned specific codes related to the research questions. These codes were then categorized into broader themes, such as occupational health risks, HIV prevention interventions, and implementation challenges. Discrepancies or contradictions in the literature were also identified and coded to highlight areas of divergence. The findings were synthesized through a narrative approach, where common themes were explored, and differences in the literature were discussed to provide a comprehensive understanding of the topic.

2.5. Interpretation and Conclusions

Finally, the findings were interpreted through coding based on the research question and existing literature. Conclusions were drawn to identify gaps in knowledge, and recommendations for future research were made.

3. Results

The initial database search yielded 312 articles. After removing duplicates, we screened 256 unique titles and abstracts for relevance. Of these, 93 articles were selected for full-text review. Applying the inclusion and exclusion criteria resulted in a final sample of 47 articles [1,2,4,6,7,9–12,15–52]. The findings were grouped into the following categories:

3.1. Occupational Health Risk for Infectious Diseases

Informal miners face a heightened risk of contracting various infectious diseases due to several factors. We grouped the available literature into three major themes.

3.1.1. Theme 1: Environmental Exposure and Sanitation

This theme focuses on the physical environment of informal mining sites and how it contributes to the spread of infectious diseases. Studies highlighted the lack of basic sanitation facilities, overcrowded living conditions, and exposure to harmful chemicals that weaken the immune system.

Poor Sanitation and Hygiene

Informal mining sites often lack basic sanitation facilities like toilets and clean water [18]. This can lead to the spread of waterborne diseases such as cholera, typhoid fever, and dysentery. Additionally, poor handwashing practices can facilitate the transmission of other infectious diseases in these settings [9]. Factors such as inadequate sanitation, lack of access to clean water, and poor hygiene practices among artisanal miners were associated with the transmission of hepatitis E in Senegal [19]. In their book chapter, Lynas, Logrosa, and Fawcett (2018) discuss how the lack of clean water and sanitation facilities increases the risk of waterborne diseases like cholera and typhoid fever [20]. Additionally, poor hygiene practices facilitate the transmission of diseases through direct contact, such as skin infections and respiratory illnesses within artisanal mining communities [20].

Overcrowded Living and Working Conditions

Overcrowded living and working conditions further exacerbate the spread of infectious diseases, creating an environment conducive to outbreaks within informal mining communities [22]. Many informal mining operations involve working in cramped and poorly ventilated spaces, especially in underground mines [23]. In South Africa, one study reported up to 16 informal miners being accommodated in a single hostel room, leading to the spread of airborne diseases due to overcrowding [24]. This proximity creates ideal conditions for the spread of airborne infectious diseases like TB and other respiratory infections.

Exposure to Environmental Contaminants

Sub-optimal dust control in the informal or non-regulated mining sector in Sub-Saharan Africa is associated with significant TB risk [21]. This risk is further compounded among HIV-positive individuals who are particularly vulnerable to TB, and silica exposure exacerbates this susceptibility [22], leading to a higher incidence of TB-HIV co-infection among informal miners. Exposure to environmental contaminants is every day in informal mining activities that often involve the use of hazardous chemicals such as mercury and cyanide in mineral extraction and processing [26]. A study found elevated levels of toxic trace metals in the blood of casual mine workers living in shacks near mining areas in Brits, South Africa [26]. Exposure to these chemicals can weaken the immune system, making miners more susceptible to infectious diseases and opportunistic infections [25].

3.1.2. Theme 2: Increased Vulnerability

This theme encompasses the factors that make informal miners more likely to come into contact with infectious agents. Studies included under this theme revealed the increased vulnerability due to the movement of informal miners across regions and high-risk behaviors like unprotected sex and substance abuse.

Migration and Mobility

Informal extractive mining often involves migration and mobility, with miners frequently moving between mining sites in search of work [24,27,29]. This can increase the risk of HIV transmission due to the transient nature of settlements and the potential for engaging in high-risk behaviors such as unprotected sex and substance abuse within these mobile communities. In Mozambique, most artisanal miners in the Cahora Bassa and Gile regions reported staying between 3 and 12 months in one location before migrating to other areas seeking new mining opportunities [28].

High-Risk Behaviors

Informal miners may engage in high-risk behaviors that increase their vulnerability to infectious diseases [22]. Factors such as multiple sexual partners, transactional sex, substance abuse, and limited access to reproductive health services contribute to the spread of sexually transmitted infections (STIs), including HIV/AIDS, syphilis, and gonorrhea, within these mining communities [22,30,31].

3.1.3. Theme 3: Limited Healthcare Access and Consequences

Studies under this theme explored how the lack of suitable healthcare services for informal miners exacerbates their infectious disease risk. Limited access to preventive care and treatment allows infections to spread and weakens their immune systems due to malnutrition and exposure to occupational hazards. This vulnerability is further amplified by the high prevalence of HIV/AIDS and STIs in these communities [16].

Informal miners typically work outside formal employment structures and often lack access to healthcare services, including preventive care, vaccinations, and treatment for infectious diseases [32–34]. This limited access inhibits timely diagnosis, treatment, and management of infectious diseases, leading to higher morbidity and mortality rates among miners and their families.

Effectiveness of HIV Prevention Programs

Various interventions, such as the distribution of condoms, peer education programs, and mobile health services, have been implemented across different mining sites. The results demonstrate a mixed effectiveness of these programs. While some sites report significant reductions in new HIV infections attributed to these interventions, others struggle with program adherence and sustainability. The variability in success rates often correlates with the level of community involvement and the consistency of program funding.

Challenges in Implementing Interventions

A major recurring theme across the studies is the emergence of challenges in implementing effective HIV prevention programs. These challenges include logistical difficulties in reaching remote mining sites, cultural resistance to behavioral changes, and the transient nature of the mining workforce. Additionally, the informal status of many mining operations complicates efforts to establish regular and structured health interventions.

In summary, informal miners face a greater risk of infectious diseases like HIV, TB, and STIs due to several factors. Poor sanitation, crowded living conditions, and exposure to dust and contaminants weaken their immune systems and make them more susceptible. Their mobility and high-risk behaviors, such as unprotected sex and substance abuse, further increase vulnerability, especially to HIV and STIs. Limited access to healthcare hinders prevention, diagnosis, and treatment, allowing infections to spread and worsen. This

situation is particularly concerning for TB, where dust exposure in mines can exacerbate existing cases or activate latent infections.

3.2. HIV Prevention Programs Implemented Among Informal Miners in Sub-Saharan Africa

3.2.1. Behavioral Strategies

Health education and behavior change communication interventions aim to raise awareness about occupational health risks, promote safer work practices, and encourage HIV prevention behaviors among informal extractive miners in South Africa [46]. In Tanzania, workshops for mining communities, including artisanal and small-scale miners, at the grassroots level, for poverty alleviation and/or eradication are utilized for communicating HIV education and behavior change messaging [49]. In Zimbabwe, among other organizations and stakeholders, the Zimbabwe Young Positives (ZY+) organization raises awareness about HIV prevention specifically within informal mining communities [45].

In the DRC, PATH implemented a targeted mobile HIV counselling and testing program for artisanal miners in four health zones of Haut Katanga and Lualaba during 2018–2019 [43]. This project offered not only testing but also prevention services (including risk reduction counselling) to those who tested negative for HIV [43]. Similar HIV prevention efforts were implemented in South Africa [50].

Peer education and support groups play a vital role in promoting health-seeking behaviors, providing social support, and empowering miners to advocate for their health rights [48]. Peer educators, trained from within the mining community, facilitate group discussions, disseminate health information, and provide referrals to healthcare services. Peer support groups offer a platform for miners to share experiences, seek guidance, and access psychosocial support [46]. In Zimbabwe, a peer-education program utilized trained peers from the mining communities to deliver information and promote positive health behaviors related to HIV prevention [44,47]. A report from the country's National AIDS Council highlighted the success of this program at Nigel West Mine in the Insiza district [44].

3.2.2. Biomedical Interventions

Pre-exposure prophylaxis (PrEP) medication acts as an antiretroviral agent that impedes the HIV replication cycle within the host. Consistent adherence to the regimen is crucial for HIV prevention. While the widespread availability of oral PrEP specifically for artisanal and small-scale miners is limited in the region, several countries have made strides to avail this critical component of HIV prevention to this high-risk group. In Zimbabwe, the Ministry of Health and Child Care, along with the National AIDS Council (NAC), spearheads national HIV prevention efforts, including offering PrEP medication to informal miners [45]. Additionally, the Zimbabwe Network of People Living with HIV (ZNNP+) plays a crucial role by supporting prevention efforts, advocating for increased PrEP awareness, and addressing negative attitudes towards PrEP among informal miners [45].

Promoting consistent and correct condom use is a crucial strategy for preventing HIV transmission among informal miners. Condom distribution programs, peer-led outreach initiatives, and workplace-based condom promotion efforts have been implemented to increase access to condoms and promote their use among miners and their sexual partners. Programs implemented in DRC and Zimbabwe have shown that condom distribution programs can lead to increased condom use and reduced rates of unprotected sex among informal miners [43,44]. Similar HIV campaigns have been implemented in West Africa [51].

Providing access to voluntary counselling and testing services for HIV/AIDS is essential for early diagnosis, treatment, and prevention efforts among informal miners. Mobile VCT units, community-based testing campaigns, and workplace testing programs have been implemented to increase HIV testing uptake and linkage to care among informal miners [52]. Evaluations have demonstrated the effectiveness of VCT services in reaching

underserved populations, reducing HIV-related stigma, and increasing awareness of one's HIV status.

3.3. Challenges and Lessons Learned in HIV Prevention Programming for Informal Miners in SSA

While various programs and interventions exist to improve HIV prevention among informal extractive miners in SSA, significant challenges hinder their successful implementation. Figure 1 shows these challenges and the lessons learned that can inform the future development and adaptation of more effective programming.

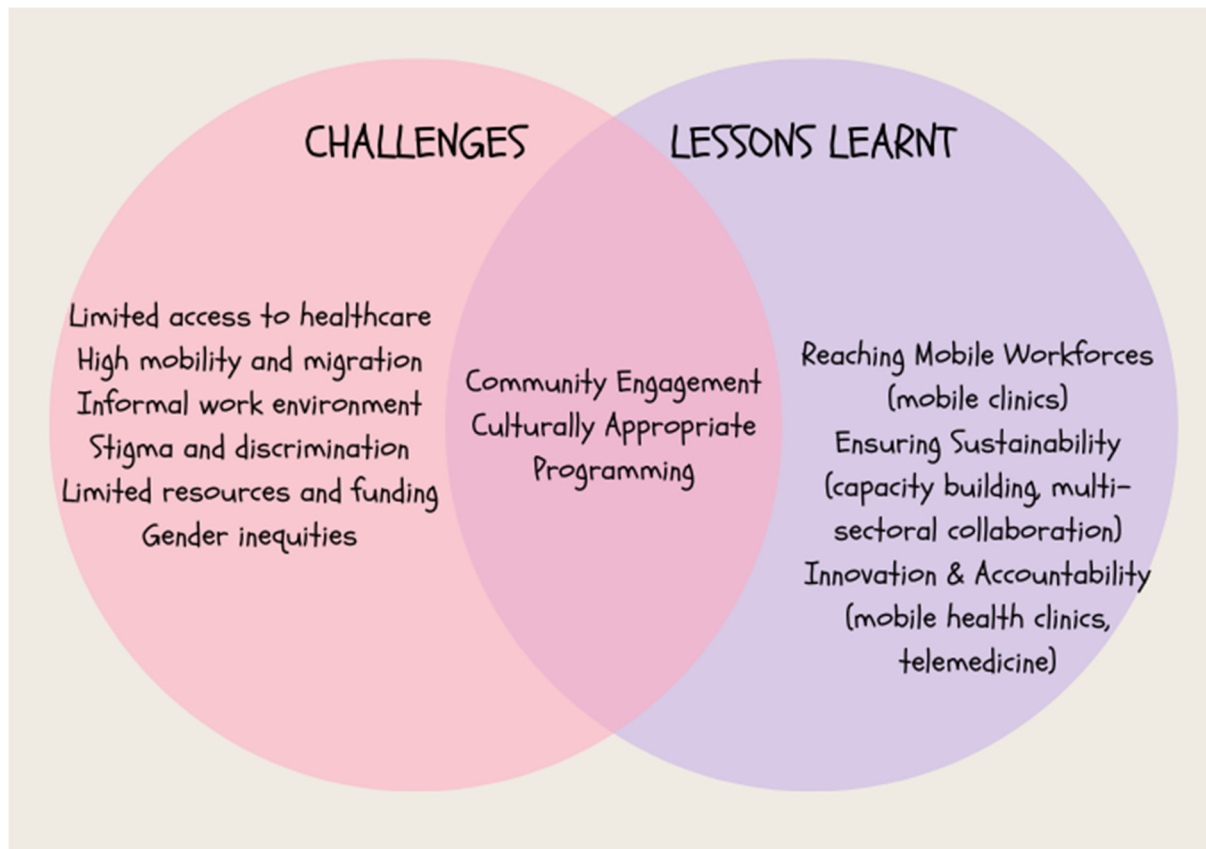


Figure 1. Challenges and lessons learned in the implementation of HIV prevention programs among informal miners in SSA.

3.3.1. Challenges

A significant challenge emerged related to access and mobility. Remote locations where mining occurs often lack basic healthcare infrastructure and services. Miners might face financial constraints that prevent them from accessing healthcare, including HIV testing and treatment [33,35,36,38]. For instance, providing regular HIV testing and treatment services directly at mining sites or through mobile clinics could be challenging due to the logistical difficulties of reaching remote areas with limited infrastructure [31]. Regarding mobility and migration, informal miners frequently move between mining sites or regions, making it difficult to track and provide consistent healthcare services [22,37]. Mobility disrupts continuity of care, especially for long-term interventions like HIV treatment programs [39]. Implementing programs that accommodate transient populations, such as mobile health units equipped for HIV testing and treatment, presents logistical challenges due to constant movement and the need for sustained follow-up care [31].

The informal work environment and stigma were identified as barriers to the implementation of sustainable and impactful HIV prevention programs among the informal mining communities. The informal nature of mining operations leads to unsafe working

conditions and limited use of protective equipment. This environment contributes to increased health risks, including exposure to HIV. Implementing workplace safety and HIV prevention measures, such as distributing condoms and promoting safe sex practices, is challenging due to the lack of oversight and regulation within informal mining settings [2,38,40]. The stigma surrounding HIV/AIDS in mining communities can lead to fear of disclosure, social exclusion, and discrimination against individuals living with HIV [33]. This discourages testing, treatment, and support services. Conducting community-based educational campaigns or workshops to combat stigma requires sensitive and tailored approaches, as fear of disclosure can be deeply ingrained in these communities.

Governments in the region often struggle to allocate sufficient resources for healthcare in remote mining areas. Limited funding results in understaffed clinics, inadequate infrastructure, and difficulty in implementing comprehensive health programs [18]. Rolling out comprehensive HIV prevention programs, such as pre-exposure prophylaxis (PrEP) or community outreach initiatives, is hindered by resource limitations, affecting the coverage and quality of services [18,31,35].

Finally, there were notable gender inequities. Female miners face unique vulnerabilities in mining communities due to gender-based discrimination and limited access to interventions [40–42]. Cultural norms may also discourage their participation in HIV prevention programs. Designing gender-sensitive interventions and outreach strategies that address specific barriers women face, such as lack of autonomy or mobility, requires additional resources and culturally sensitive approaches to be effective.

3.3.2. Lessons Learned

Implementing successful HIV prevention programs among informal miners in Sub-Saharan Africa requires a multifaceted approach that incorporates lessons learned from community engagement, culturally appropriate programming, service integration, mobile outreach strategies, advocacy for policy change, sustainability through livelihood diversification, and capacity building. Community engagement is pivotal, emphasizing active collaboration with mining communities and local leaders to foster trust and address cultural beliefs impacting health behaviors [1]. Tailoring interventions to the specific cultural context and literacy levels is essential, utilizing peer education and locally relevant messaging to promote safer work practices and HIV prevention. Integrating occupational health with HIV prevention services expands program reach [2], encouraging miners to access essential healthcare like VCT. Mobile outreach programs, employing health education and service delivery vans, overcome geographical and workforce mobility challenges. Advocacy efforts to formalize the informal mining sector and strengthen safety regulations create an enabling environment for health interventions. Promoting alternative livelihoods reduces mining dependence and fosters investment in safety. Capacity building for healthcare providers and community health workers ensures sustainability, empowering informal mining communities to take charge of their health [10]. Multi-sectoral collaboration, including governments, NGOs, mining companies, academia, and civil society, leverages expertise and resources to develop comprehensive interventions. Innovations like mobile health clinics and telemedicine bridge geographical gaps, enhancing program effectiveness and accountability. Strengthening regulatory frameworks protects miners' health and rights, prioritizing policy reforms that formalize mining activities and promote sustainable practices to minimize risks [9,32]. Through these strategies, alongside consideration for gender issues, HIV prevention efforts can effectively address the complex health challenges facing informal mining communities in Sub-Saharan Africa.

One significant revelation was the critical role that localized social dynamics play in the effectiveness of HIV prevention programs. For instance, interventions that included elements of social support, such as peer education and community involvement, showed markedly better outcomes compared to those that did not. Studies that incorporated peer education programs reported increased uptake of voluntary counseling and testing (VCT) services, higher levels of condom use, and improved adherence to ART. These interventions

benefited from miners' trust in their peers, fostering open discussions about HIV prevention and reducing stigma associated with seeking care. Community involvement initiatives, such as forming local health committees or engaging mining community leaders, also resulted in enhanced program reach and sustainability by tailoring interventions to local needs and encouraging collective ownership of health initiatives.

In contrast, programs that lacked social support elements, relying solely on information dissemination or generic health campaigns, demonstrated limited effectiveness. Such interventions often faced challenges like low participation rates and minimal behavior change, attributed to miners perceiving these programs as externally imposed and less relevant to their socio-cultural contexts.

Another intriguing finding was the apparent efficacy of integrating HIV prevention with broader health and safety programs at mining sites. Studies suggested that when miners perceive direct benefits to their health and safety beyond HIV-specific interventions, their participation in prevention programs increases. This holistic approach not only addresses the immediate health risks but also contributes to a general improvement in health awareness and practices among miners.

These insights have profound implications for future research and the implementation of HIV prevention programs. They suggest that future studies should explore the specific elements of social support and community involvement that are most effective in different mining contexts. Additionally, integrating HIV prevention with other health interventions could be a promising area for developing more comprehensive health programs. These strategies could potentially increase the overall health outcomes for informal miners and provide a more sustainable model for health intervention in these high-risk settings.

4. Discussion

The findings from our review offer significant insights that both challenge and support existing theories and practices in public health, particularly within the framework of health behavior change and disease prevention in high-risk populations. Traditional health behavior change models, such as the health belief model [53] and the theory of planned behavior [54], suggest that individual decisions are primarily influenced by perceived risks and benefits, social norms, and perceived control over outcomes. However, our findings emphasize the critical role of environmental and situational factors in shaping health behaviors among informal miners, a group frequently exposed to extreme and unique risks. These insights align with more contemporary models like the Ecological Model of Health Behavior [55], which advocate for considering the multiple layers of influence on an individual, including policy, community, and organizational factors.

Our research highlights how interventions that are culturally tailored and involve community participation not only support these theoretical frameworks but also demonstrate greater effectiveness in practice. This challenges the traditional top-down approach to health programming [56] and supports a more participatory and context-sensitive planning process. The successful integration of HIV prevention with broader occupational health initiatives further underscores the importance of a holistic approach to health promotion, as posited by the settings-based approach to health promotion. This approach suggests that health cannot be achieved by focusing on the individual alone but requires changes to the entire system that affects people's lives. By linking these insights to established health theories, our study advocates for a shift in how health interventions are conceptualized and implemented in high-risk settings, suggesting that effective disease prevention must address the complex interplay of individual, environmental, and systemic factors.

We propose a conceptual framework (Figure 2) for designing successful and impactful HIV prevention programs among informal miners in SSA. This framework acknowledges the unique challenges found and reported in Section 3 and the holistic approach of addressing the complex interplay of individual, environment and other systemic factors. To overcome these hurdles, the framework emphasizes a multifaceted approach that prioritizes community engagement, culturally appropriate programming, and integration of

occupational health with HIV prevention services. Effective service delivery strategies are crucial, utilizing mobile outreach programs, peer education, and telemedicine/mobile clinics to reach this geographically dispersed population. Sustainability and empowerment are fostered through advocacy for policy changes and formalization of the mining sector, livelihood diversification to reduce dependence on mining, and capacity building for healthcare providers and community health workers. Finally, the framework underscores the importance of multi-sectoral collaboration between governments, NGOs, mining companies, academia, and civil society to strengthen miner health and safety regulatory frameworks, ultimately contributing to successful program implementation.

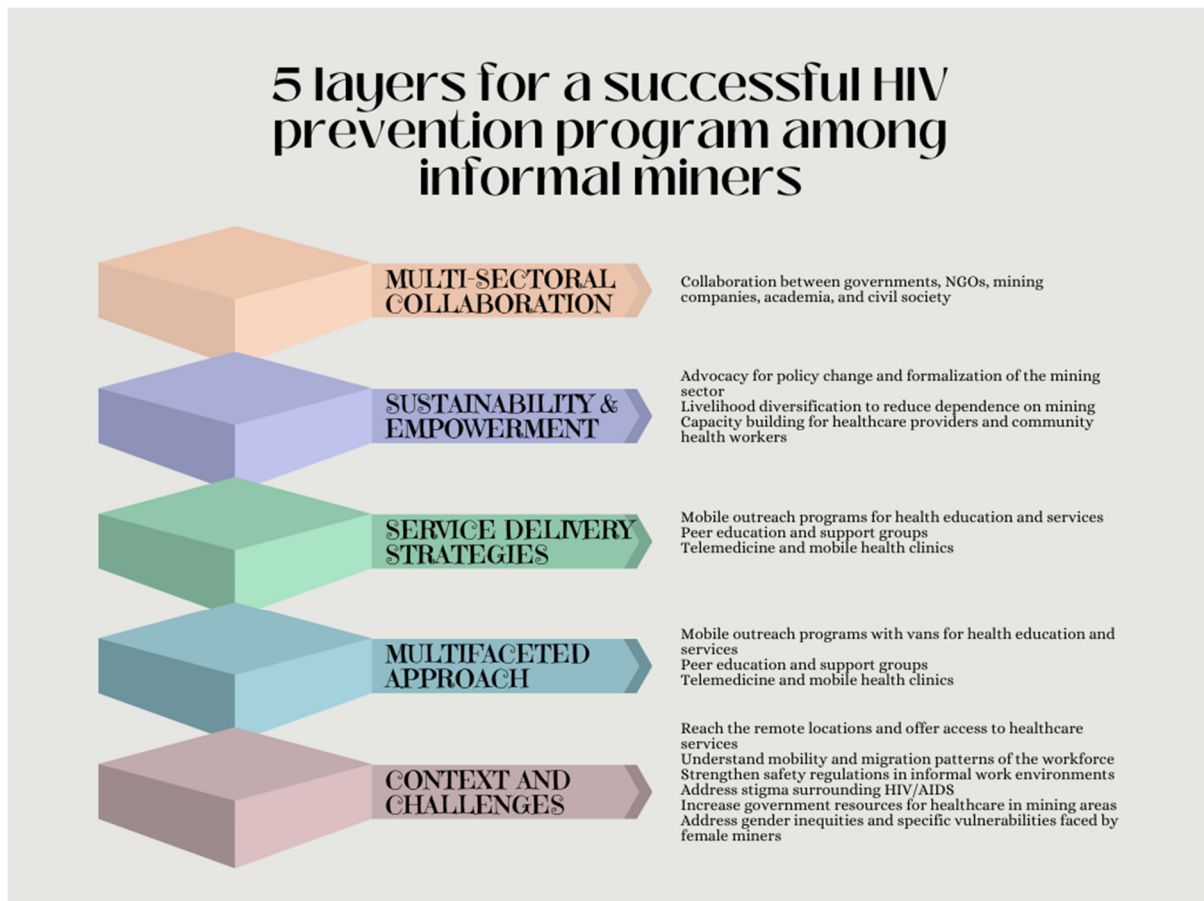


Figure 2. Conceptual framework for designing successful and impactful HIV prevention programs among informal miners in SSA.

This conceptual framework provides a structured approach to the key components needed for successful HIV prevention programs among informal miners. It emphasizes the importance of addressing the context and challenges, using a multifaceted approach, employing effective service delivery strategies, ensuring sustainability, and fostering multi-sectoral collaboration.

4.1. Implications for Policy and Practice

The findings from our review carry significant implications for both health policy and mining regulations. They underscore the necessity for integrated health services and targeted interventions that address the unique challenges faced by this population. Given the effectiveness of community-based and culturally tailored approaches, health policies should prioritize the development and funding of programs that are designed with significant input from the mining communities themselves. This could involve formal-

izing collaboration between health services and mining operations to ensure that health interventions are accessible on-site and tailored to the miners' specific needs and risks.

Furthermore, the evidence supports the need for revising mining regulations to incorporate mandatory health and safety standards that include provisions for infectious disease prevention, such as HIV. Strengthening these regulations could significantly reduce the occupational health risks that contribute to the high incidence of HIV among miners. Governments, particularly ministries of health and labor, can play a key role in implementing these changes by enacting and enforcing laws that require health and safety measures as a standard part of mining operations.

International NGOs and agencies that focus on occupational health, such as the World Health Organization (WHO) and the International Labour Organization (ILO), can also be influential. They can provide the necessary technical support and advocacy to ensure that these health policies and mining regulations are developed based on best practices and robust evidence. Furthermore, these organizations can assist in mobilizing resources and facilitating partnerships that can drive the implementation of these policies on the ground.

Interventions incorporating social support, such as peer education and community involvement, consistently demonstrated stronger outcomes than those lacking these elements. These findings underscore the importance of culturally and contextually adapted approaches. Programs that integrate peer education and community involvement not only achieve higher engagement but also foster a sense of shared responsibility, leading to more sustainable outcomes. Future research should explore specific mechanisms through which social support enhances program effectiveness, such as reducing stigma or increasing trust in healthcare services.

4.2. Call to Action

There is a clear need for more robust funding and strategic support for mobile health clinics, which have proven essential in reaching remote mining communities. Additionally, integrating HIV services with broader health and safety programs at mining sites can significantly amplify the impact of these interventions. Stakeholders must collaborate to ensure these initiatives are not only implemented but also adequately supported to adapt and expand as necessary.

A key element that should be emphasized in the response is the unregulated nature of the informal mining sector, which remains a central challenge to effectively addressing the health risks faced by miners, including HIV. A robust regulatory framework is crucial not only to mitigate HIV risks but also to tackle the upstream determinants of HIV infection, management, and control, such as poor sanitation, exposure to environmental hazards, and limited healthcare access. The absence of a formal regulatory structure has exacerbated these risks, with studies highlighting how the informal status of mining operations complicates the implementation of health interventions. To address this gap, policy development efforts should focus on establishing clear guidelines for regulating informal mining activities, improving occupational health and safety standards, and enhancing access to healthcare. A strategic approach could involve collaboration between governments, mining communities, and international organizations to create and enforce regulations that go beyond HIV prevention to address broader social and environmental determinants of health.

4.3. Future Research Directions

Future studies should focus on evaluating the long-term outcomes of integrated health interventions to determine their sustained impact on HIV prevention. Research should also explore the effects of legal reforms on health access for miners, particularly how changes in mining regulations can improve health outcomes. Further investigation is needed into the scalability of successful models across different mining contexts and regions, identifying factors that facilitate or hinder their effective implementation.

4.4. Sustainability and Scalability

For the sustainability and scalability of HIV prevention programs, it is crucial to consider economic, environmental, and social factors. Economic analyses should assess the cost-effectiveness of various interventions to ensure that limited resources are utilized optimally. Environmental assessments must consider the impact of mining operations on health and safety practices, promoting sustainable practices that support health outcomes. Socially, programs must be culturally sensitive and inclusive, particularly addressing the needs of vulnerable groups within mining communities, such as women and transient workers.

5. Conclusions

Overall, while efforts have been made in implementing programming and interventions to address occupational health risks and HIV prevention among informal extractive miners in SSA, multiple barriers are encountered. These include limited access to healthcare services, inadequate funding, weak regulatory enforcement, and social and cultural barriers to behavior change. To enhance the effectiveness and sustainability of interventions, stakeholders need to prioritize community engagement, strengthen health systems, address structural barriers, and adopt a multi-sectoral approach that addresses the underlying determinants of health in mining communities. Building on lessons learned from existing interventions and scaling up proven strategies, HIV programs in the region can work towards improving the health and well-being of informal miners and achieving the goal of HIV epidemic control.

Our review has examined the challenges and opportunities within HIV prevention programs for informal miners in Sub-Saharan Africa, revealing key insights into the efficacy of current interventions and the critical areas needing enhancement. Given the complex interplay of occupational hazards, socio-economic factors, and healthcare accessibility that characterize the mining sectors in this region, a concerted effort from all stakeholders is imperative to drive meaningful progress.

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