Occupational health and safety challenges among artisanal and small-scale diamond miners in Kimberley, South Africa

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ABSTRACT

Background: Artisanal and small-scale mining (ASM) is a laborious process often executed with rudimentary low-technology mining equipment. It exposes miners to a myriad of occupational hazards, which may increase health and safety disparities between them and formally employed mine workers.

Objectives: The objectives of the study were to identify workplace hazards and the associated risks; and to assess the effects of mining activities on the health and environment of artisanal diamond miners in Kimberley, Northern Cape province.

Methods: This was an interdisciplinary observational ethnographic study. A workplace assessment was undertaken at seven sites in Kimberley. Participants were conveniently selected; snowballing was used to recruit additional participants. Field notes were recorded from observations. Interview questions included those about the duration of artisanal mining, and the risks faced in the workplace. Data collection included photographic documentation. An inductive and deductive process was used to analyse the data and thematic analysis was conducted.

Results: The observed occupational hazards included physical (ultraviolet radiation exposure, injuries due to trauma), respiratory (silica dust exposure), biomechanical (heavy lifting, repetitive movement), and psychological (work-related stress, anxiety) hazards. There was a paucity of access to, and use of, personal protective equipment (PPE). Workers improvised ways to protect themselves, e.g. by using cloths as masks. There was no recourse to formal occupational health services and social safety networks.

Conclusion: Occupational health and safety challenges included physical, biomechanical, respiratory, and psychosocial hazards. The mining activities had a detrimental impact on the environment.

INTRODUCTION

Kimberley is an historic diamond mining town located in the Northern Cape province of South Africa. The first diamond discovered in South Africa, named Eureka, was found in 1867 near Hopetown, 125 km from Kimberley. Mining activities over the years in Kimberley resulted in mine tailings being dumped throughout the city. An improvement in metallurgical processes resulted in the reprocessing of these tailings.[1] Running parallel to this, an 'illegal' artisanal small-scale mining (ASM) industry emerged. Large-scale mining (LSM) refers to formal highly industrialised mining, usually undertaken by large mining companies. Small- scale mining (SSM) refers to mining that combines mechanised and artisanal processing and is conducted by individuals or small companies. Artisanal small-scale mining refers to mining that is done by hand with rudimentary equipment, mainly by subsistence miners.

The mining and metallurgical processes and the rudimentary equipment used in small-scale mining predispose the miners to several hazards. The impact on the health of ASM communities is broad and complex.[2] Health issues such as sexually transmitted infections (including HIV), skin conditions, parasitic infections, tuberculosis, sinusitis, allergies, malnutrition, and heat stroke are not uncommon.[3,4] Silica dust exposure is toxic to the lungs and may predispose to pulmonary and respiratory disorders such as tuberculosis, aggravation of upper airway problems, e.g. sinusitis, and have latent effects including lung cancer.[5,6] Repetitive movements due to sieving and hauling heavy buckets of sand, and other activities, predispose the miners to biomechanical injuries.[5] ASM also exposes miners to psychological stressors.[5]

Social issues such as poverty, job insecurity, food insecurity, poor housing, lack of water and sanitation amenities, drug- and alcohol-associated health problems, and criminality further contribute to the burden of disease in these communities.[7] Women in these communities often experience gender-based violence, commercial sex exploitation, and the added burden of mining and attending to domestic responsibilities.[5] Child labour is common in ASM and poses a risk to the health and social development of children.[8]

The control of degradation and rehabilitation of the environment in the ASM sector is complicated by the lack of enforcement of regulatory and legal policies, e.g. issuing licences to artisanal miners so they can mine certain areas legally.[9] Destruction to the environment also poses an occupational hazard, resulting in risk of injuries.[10]

The study presented here forms part of a larger project, called *Eureka*, the main aim of which was to explore the public health and social impact of artisanal mining in Kimberley. *Eureka* was a transdisciplinary study, drawing on the disciplines of fine art, public health, and occupational health. The objectives of the study reported here were to identify workplace hazards and the associated risks; and to assess the effects of mining activities on the health

and environment of artisanal diamond miners in Kimberley. *Eureka* was undertaken by researchers who are both artists and academics, with experience in community art-based projects and public health medicine, respectively.

METHODS

The study comprised two parts, viz. an observational ethnographic study design with community participation, and a workplace hazard and risk assessment. This design was chosen because we wanted to conduct an exploratory study to understand the occupational context of the artisanal miners in an inductive and holistic way.[11] It was important for us to allow the mining community to be part of the process. This we achieved by having consultations with the mining community, followed by visits to speak to people that they identified for us.

The study was undertaken in Kimberley in the Northern Cape province of South Africa. A scouting visit was conducted in 2015 to identify potential study sites, after which we met with mining community members. We focused on three areas where artisanal mining activities were taking place, namely Samaria, Beefmaster, and Colville – the largest and longest-standing sites. Samaria and Beefmaster are the names given by the miners to the areas in which they were mining. They lie adjacent to each other and are separated by (fast-disappearing) mine dumps. These two areas rapidly developed into informal mining settlements from 2015 onwards. They are characterised by makeshift informal housing, no roads, water or sanitation infrastructure, and no health services. The Colville mining site is located in the immediate vicinity of a formal low-socioeconomic housing neighbourhood. All three areas are characterised by mine tailings that have been dumped in the area from formal mining activities, over decades. We visited four other areas where artisanal mining was being conducted, viz. Green Point, Floors, Square Hill Park, and Gum Tree. The seven study sites were purposively selected because they were the main sites where artisanal mining was taking place. Figure 1 illustrates where the mining areas are located within the municipality limits of Kimberley.

The study population comprised artisanal miners at the mining sites, community leaders, and people living in the mining community who were not directly involved with mining, e.g. spouses, and included both South African citizens and undocumented foreign nationals. The miners are highly mobile. Some have been part of the mining community for several years but, in general, during the study period, people had worked there for no more than two to four years. Miners came to prospect and later left, either because they did not gain the anticipated wealth, or because they found other employment opportunities.

In 2015, there were 100 to 200 people mining at the seven sites combined. This number steadily increased over the years and, by March 2022, the estimated number of people living in Beefmaster and Samaria was 2 000–3 000, of which at least a quarter were engaged in mining.

These communities are largely 'invisible', difficult to reach, and covert. Study participants were conveniently selected when a site was visited, and we used snowballing to recruit additional participants. We included miners who were South African, undocumented miners, and people living at the sites who were not actively mining. We interviewed participants until we reached data saturation.

Data collection

We collected data from participants, using an interview guide (Supplementary Appendix A). We asked where they came from, how long they had been working there, why they were working there, the perception of the risks to their health and safety, and how they thought their workplace safety could be improved.

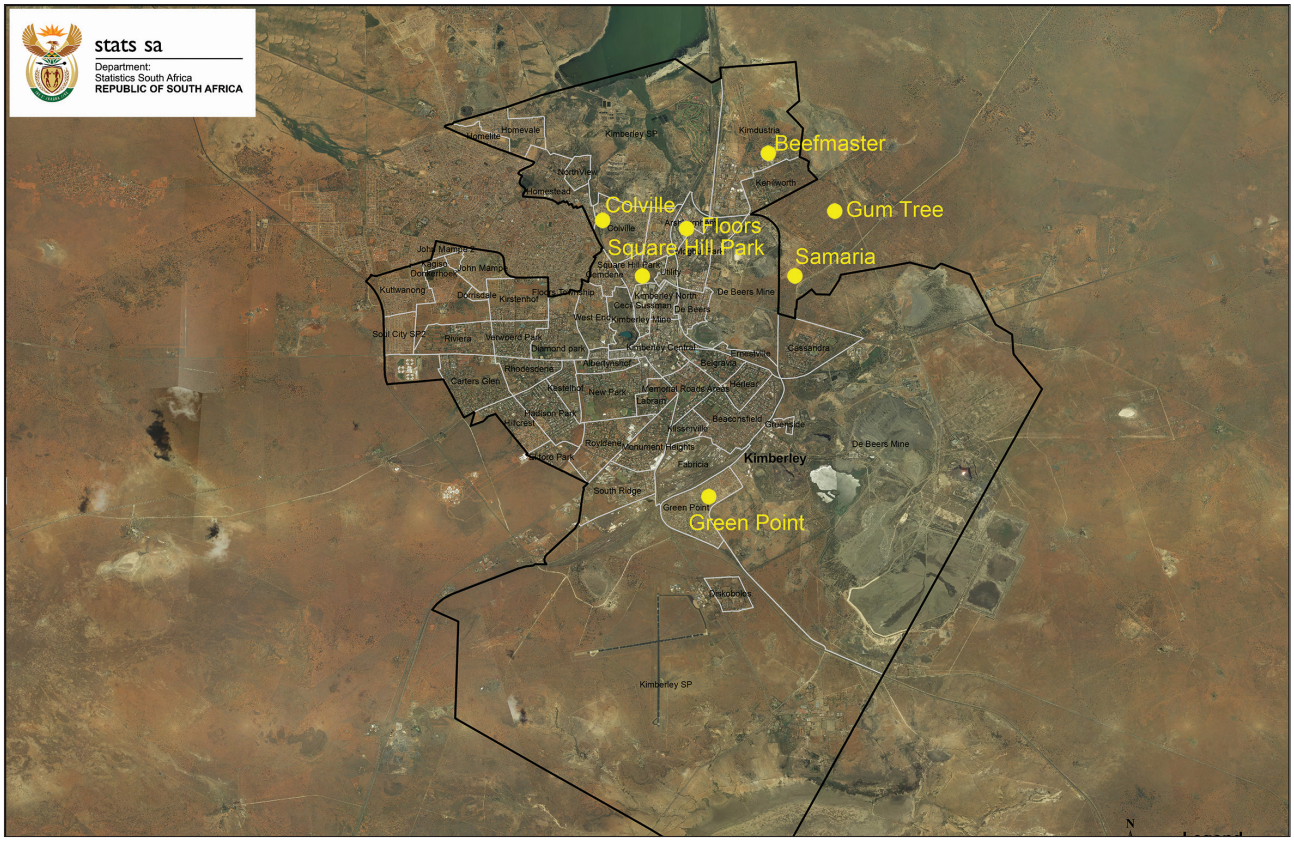

Figure 1. Map of Kimberley, indicating artisanal mining areas
(Source: Statistics South Africa)

We conducted a workplace hazard and risk assessment using a modified tool from the National Institute for Occupational Health (NIOH)[12] and the the UK Health and Safety Executive's (HSE's) 5-Step Risk Assessment.[13] Although these tools were developed for a formal industrialised work process, the hazards and risks in artisanal mining are similar. This modified tool allowed us to assess what physical, chemical, respiratory, and/or psychological hazards were present in the workplace, and to quantify the health and safety risks.

Data were collected from 2015 to 2022 during 10 site visits. We restricted visits from early 2020 to late 2021 due to the COVID-19 pandemic lockdown restrictions. During the initial visits we spoke to people in the mining community, getting to know who they were and what they were doing, identifying the community leaders, and observing the miners at the mining sites. The workplace assessments and interviews were conducted at different times – in 2016 and 2017, and between 2015 and 2022, respectively.

Community leaders held meetings and obtained permission for us to work in the mining community. As we developed rapport with the community members, they started sharing their experiences and challenges. We conducted individual in-depth conversations and group discussions with two to three people who were working together at a claim. Most of the interviews were conducted at Beefmaster and Samaria because these were the larger sites. In total, we interviewed 30 people over a seven-year period. We spoke mainly to the miners, but also to people in the mining community who were not actively mining.

We recorded our findings in field notes and with photographs. We triangulated our data, using media to further inform us of what was happening in this community. The community leaders periodically contacted us to share information about what was happening in the community.

We conducted workplace assessments on two occasions, in 2016 and 2017, using the modified tool described above.

We also did a 'walkabout' at three sites, using a tick sheet as a guide. These three sites were the largest of the seven, as mentioned. Additionally, the Green Point and Square Hill Park sites were no longer operational, and the others were not yet established, at the time of the assessments in 2016 and 2017.

The study was approved by the Health Sciences Research Ethics Committee of the University of the Free State (HSREC121/2015). All participants were repeatedly informed that this was a research project; the nature of the project was explained to them, and verbal consent was given by them to include their experiences and images in the study.

Data analysis

A thematic analysis was done using deductive and inductive approaches. We decided on the themes based on the literature (deductive approach) and allowed themes to emerge from the data (inductive approach). We worked together to refine the themes and to agree on which ones should be included.[14] Risks were quantified as severe (fatal or severe disability), moderate (recovery within 14 days), and negligible ('near miss' or unlikely to happen). The exposure was quantified as unlikely, possible, or likely. The risk was calculated as the product of the consequence of the risk and the likelihood of exposure.

RESULTS

Interviews

The participants reflected on a variety of issues, which we grouped into themes, such as hope and dreaming, impact on the environment, and health and safety. Hoping and dreaming for a better future emerged strongly among all the participants.

"I want to build a house and I want to open a shop, a big shop like a supermarket." P5, Beefmaster

The majority of participants reflected that the work they were doing was very difficult and labour intensive, but they felt they had few other options. They stated that they felt compelled to be working there because of high unemployment rates.

"There are no jobs. I have to feed my family and I don't want to steal to feed them." P8, Samaria

The participants did not think that they were destroying the environment by their mining activities.

"We don't destroy the veld, it's the big mining companies that destroy the environment. They have big machines, and they destroy it [the environment] *we use spades to dig up the soil and everything* [the veld] *grows back again."* P11, Beefmaster

Women reported high levels of stress related to gender-based violence and fear that they would not be able to provide for their children.

"I am afraid they will attack me at night. It's very dark here, there are no lights. The men get very drunk, it's not safe." P4, Samaria

A major theme that emerged was the poor use of personal equipment.

"I have gloves. I use the gloves because the work is 'rof' [rough]. *The rocks hurt your hands. But you can see the gloves are broken. I can't buy new gloves every time."* P3, Beefmaster

"We don't use masks. There is a lot of dust but where must we get the masks from?" P7, Samaria

"I used to work in the mines and I have this mask but you can see the dust is already thick." P12, Gum Tree

Another theme was occupational hazards.

"This is not easy work but you don't get injured and I don't use anything to protect me. I don't think it's necessary." P4, Samaria

"I have never seen anyone trip and fall into these holes. I don't think it happens a lot. Me, I have not seen anyone get hurt here." P11, Samaria

"The main problem here is the heat. It gets very hot but what can you do you have to work." P9, Beefmaster

"The work is so stressful. You hope you will find something, maybe just to eat. The work is hard and people they make too much noise at night, and it is hot in the house and you cannot sleep properly. It is just too much." P3, Samaria

Workplace assessment

The findings from the workplace assessments were similar in 2016 and 2017. There was a medium risk of trauma from the mining as all activates were on the surface, and the holes dug were generally not deep enough to pose an imminent risk to the workers

Table 1. Workplace hazard and risk assessment across three mining sites (Samaria, Beefmaster, and Colville) in Kimberley, 2016 and 2017

Risk matrix		**Likelihood of exposure (L)**		
		Unlikely: Highly improbable	**Possible:** May be experienced once a year by an individual	**Likely:** May be experienced once or twice a year by an individual
Consequence of exposure (C)	**Severe:** Fatal or permanent disability	**Medium**	**High**	**Very high**
	Moderate: Recovery within 14 days	**Low**	**Medium**	**High**
	Negligible: Near miss or unlikely to happen	**Very low**	**Low**	**Medium**

Risk Assessment								
Hazard	Task/activity	Health effect	Final risk level (R)*					
			Very low	Low	Medium	High	Very high	
Physical/biomechanical								
Trauma	Crushing agglomerate, falling into holes and trenches	Ocular injury, soft tissue injury, fractures						
Repetitive movements	Sieving, hauling	Joint and soft tissue inflammation						
Heavy lifting	Hauling extract	Back pain						
UV radiation	Sun exposure	Sunburn, skin cancer (long term)						
Heat exhaustion	Exposure to the environment	Fatigue, electrolyte disturbances						
Respiratory								
Silica dust exposure	Dust generated by sieving	Sinusitis, respiratory diseases, silicosis, lung cancer (long-term)						
Psychological								
Work-related stress	General mining activities	Anxiety, fatigue, sleep disorders, decreased concentration, work injuries, interpersonal relationships, conflict, substance and alcohol misuse and abuse, gender-based violence						
Anxiety								
Burnout								

*C x L (consequence of exposure x likelihood of exposure)

(Table 1). There was the potential for trauma because of the use of rocks for crushing conglomerate, and resultant flying objects that could cause ocular trauma. The repetitive movements of digging, hauling, and sifting resulted in shoulder girdle muscular pain and tension. The exposure to ultraviolet (UV) radiation and excessive heat meant that the workers are at high risk of heat exhaustion. The risk of poor mental health was rated high because of activities related to living and working conditions.

Observations

The study sites comprised dry surface diggings; no underground mining was observed. The mining was done mainly by men. A few women performed labour directly related to mining but were primarily involved in domestic activities at the mining settlements. We did not observe any children directly involved in the mining process. There were many migrant workers: miners included South African citizens from across the country (North West, Western Cape, Eastern Cape, and Free State provinces), and workers from Malawi, Lesotho, Mozambique, and Zimbabwe. Mining activities resulted in soil excavation resulting in soil erosion, and destruction of the natural vegetation. There was no evidence of environmental rehabilitation by the artisanal miners. There was no access to reliable water sources, sanitation, or health services (including occupational health services).

The extractive process at the Kimberley mining sites entails excavating individual mining claims, which are usually no more than 2 m^2 (Figure 2). The excavated soil is hauled to an adjacent site for sieving, breaking up bulky conglomerates using hammers or rocks, and then sorting the extracted ore by hand (Figures 3 and 4). The extractive process at these sites was conducted primarily using hand shovels and pickaxes, rough wooden frames for sieving, and large (usually 20 litre) plastic buckets for hauling sand (Figure 5). The equipment was rudimentary and handmade, with no mechanisation. Some tools were either handmade or were improvisations. For example, rocks or bricks were used to crush agglomerate (Figure 6).

There was a dearth of protective clothing and other personal protective equipment (PPE) such as gloves, eye protection, and dust masks. The majority of 'zama zamas' (artisinal mine workers) did not wear any respiratory protection (Figure 4). The was a paucity of individual and collective protection against hazards, e.g. there were many open holes and trenches that had been dug out (and that filled up with water when it rained) (Figures 7 and 8). In the case where dust masks were worn, they were either makeshift masks made from cloth or were inappropriate and ill-fitting masks, covered with a thick layer of dust, and most likely ineffective against respirable dust.

The photographs we collected illustrate major occupational health and workplace challenges. In Figures 3 and 4, exposure to dust is illustrated; no respiratory PPE is used. Figures 2 and 5 illustrate the low-technology equipment used. Figure 6 shows the use of gloves, and a brick to crush the agglomerate. Figures 7 and 8 illustrate the safety hazard that open ditches and pits posed to workers, children, and others in the communities.

Figure 2. Low-technology mining equipment (2018) (Square Hill Park) *Photograph: André Rose*

Figure 3. Dust exposure from sieving (2018) (Square Hill Park)
Photograph: André Rose

Figure 4. Dust exposure from sieving, lack of respiratory PPE (2018) (Square Hill Park) *Photograph: André Rose*

Figure 5. Buckets used for hauling (2018) (Square Hill Park)
Photograph: André Rose

Figure 6. Gloves used as PPE; brick to crush agglomerate (2018) (Square Hill Park) *Photograph: André Rose*

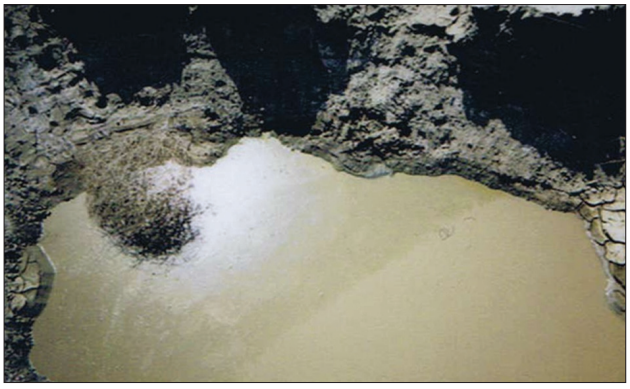

Figure 7. Water-filled ditches posing hazard for injury (2022) (Beefmaster) *Photograph: Janine Allen-Spies*

Figure 8. Deep open pits posing a hazard for injury (2022) (Colville)
Photograph: Janine Allen-Spies

DISCUSSION

Artisanal and small-scale mining is plagued by a myriad of challenges, including geology (poor access to quality-ore bodies), technology factors (no access to safe or mechanised equipment), human resources (unskilled labour force), finances (little or no access to formal capital investment), and absent marketing (lack of access to formal markets).[10,15] These mining communities often lack structured organisations to guide and monitor mining activities, which may be fractured within the communities when they do exist.[10] Furthermore, ASM communities are exposed to exploitation by highly organised (criminal) syndicates.[16] Similar to Ledwaba (2017),[15] we observed all of these challenges in the mining communities we studied.

Mining activities are often conducted under precarious circumstances and the hazards may pose low to high risks, and may even be fatal.[17] These risks may be mitigated through a hierarchy of control measures, which range, in decreasing effectiveness, from elimination, substitution, engineering controls, and administrative controls, with the least effective being the use of PPE.[18] The risks may be exacerbated in ASM operations because of a lack of access to mitigating resources. The mining communities had minimal protective measures in place and had few or no resources that could ensure safer workplaces.

Substitution, engineering, and administrative controls could be effected if the 'zama zamas' had access to knowledge from large-scale mining (LSM) and Government structures, such as the Department of Mineral Resources and Energy (DMRE) and the Department of Employment and Labour (DEL).[10] Large-scale mining companies could play an important role in improving mining health and safety in ASM operations by granting these miners access to their services through, for example, corporate social responsibility initiatives.[19] There were, however, no opportunities created for the ASM and LSM parties to engage with each other to facilitate such debate. This may be a consideration for negotiation between the two entities.

The psychological risk in the ASM communities was assessed as high. The lifestyle and occupational stressors of ASM interact, resulting in psychological stress, anxiety, depression, and sleep disorders.[4] The psychological impact on health may also manifest physically.[10] Large-scale mining companies often have well-established employer wellness services and there may be an opportunity for them to extend these services and programmes to ASM communities.

Our workplace risk assessment rated physical trauma and biomechanical injuries as a medium risk. The artisanal miners were only engaged in surface operations, which significantly reduced their occupational safety risks. This risk could, however, be further reduced with simple control measures, such as availing LSM engineers to help the ASM miners re-engineer their equipment, the mechanisation of some processes, and availing micro-financing to purchase safer equipment.[3] Hauling heavy bucket loads of sand, for example, could be improved by introducing pulley systems. Training in ergonomics could reduce repetitive movements injuries.[20] Although there was a medium risk for trauma, the risk could be further mitigated by formalised staking of claim sites, to avoid slips and trips into holes and trenches.

PPE utilisation is the least effective way to mitigate risk, but it offers an opportunity to reduce health and safety risks in these workplaces. The inaccessibility to protective eye wear, dust masks, gloves, and safety boots potentiates the likelihood of injury among these miners. Accessibility is, however, not the only factor to be considered, as poor PPE compliance is often a bigger hurdle.[3] Access, cost, and education on the use of PPE is a roadblock to improving health and safety in ASM communities.[3] It would be prudent if the DEL and the DMRE conducted a cost benefit analysis on how financing the hierarchy of controls[18] in ASM communities could alleviate the burden of disease and be cost saving to the health system.

Respirable crystalline silica (RCS) dust particles may cause pulmonary disease (bronchiolitis, obstructive lung disease, and silicosis), kidney disease, and lung cancer as RCS is a recognised carcinogen.[21] These diseases often have long latency periods and may only present years after the 'zama zamas' have stopped mining. Silica dust exposure may result from inhalation of dust from digging and sieving processes. Exposure to RCS was assessed as a very high risk and steps need to be taken to reduce this.

Silicosis and other occupationally related diseases and injuries are compensable in South Africa.[21,22] The 'zama zamas', however, have little recourse for compensation as they are regarded as illegal workers and, in most cases, they do not have an employer contributing to the Compensation Fund. Miners from outside South Africa may return to their home countries, thereby transferring the health burden.[23] Occupational diseases, injuries, and fatalities may push people further into poverty because they have to pay for health services, and are not able to work with the added burden of disease. This further widens the health equity gap.

Artisanal and small-scale mining is a complex adaptive ecosystem, which is impacted by a myriad of complex interactions such the social determinants of health, environmental factors, demographic shifts, and economic paradigms, which interact in a non-linear fashion.[5,24] The transformation needed to reform the ASM sector must consider the complex ecology of the sector. The United Nations (UN) Sustainable Development Goal 8 (SDG 8) focuses on three issues: economic growth, productive employment, and decent work.[25] Artisanal and small-scale mining presents an opportunity to assist in meeting the objective of alleviating poverty by increasing employment opportunities.[8] It can also reduce rural-urban migration movement by offering communities sustainable opportunities in rural areas. The social consequences of ASM are probably the most devastating impact on these mining communities.[7] Developing the contribution that this sector can make to economic growth could help reduce the impact of the social determinants of health on these communities.[1] Synergy between ASM and LSM has the potential to transform the ASM sector, and help alleviate unemployment and improve the socioeconomic status of ASM communities. This can have positive ripple effects on these community members' health. The complex interactions identified in the study included the interaction between the need to work and the roadblocks that the 'zama zamas' experienced in creating a safe workplace.

The trustworthiness of the study was supported by fact that the findings are congruent with what is reported in the literature, and that the researchers are experienced in community-based research. Furthermore, one of the researchers is a public health medicine specialist with experience in occupational health and workplace assessments. The researchers developed rapport with specific miners and community leaders over the study period, and connected with them when they conducted repeat visits, adding weight to the credibility of the findings.

The views expressed by the participants are unique to them and, therefore, the findings might not be generalisable to other artisanal miners. There are no validated tools for assessing hazards in informal mining and so we adapted a tool used for formal industrial processes, which is another limitation of this study. However, a strength of the study is the transdisciplinary approach, which offered a multifaceted

perspective on this complex issue. There is a paucity of data on diamond ASM communities, to which this study contributes.

Future research should consider a mixed-methods approach, using qualitative methods to further explore the challenges that ASM communities face, and quantitative methods to assess the impact that occupational activities have on the miners' physical and mental wellbeing. Future studies should also extend to at-risk populations within these communities, e.g. women, children, and undocumented miners. Regulatory and legal frameworks need to be reformed to protect artisanal miners.

CONCLUSION

The 'zama zamas' in Kimberley face occupational health and safety challenges, which include physical and biomechanical, respiratory, and psychosocial hazards. They were at risk of joint and soft tissue injuries due to repetitive motions; dust exposure placed them at risk for upper respiratory diseases, and silicosis. The work environment resulted in high levels of stress and anxiety, which can affect mental wellbeing. There were also risks of trips and falls. Mining activities had a detrimental impact on the environment. The complexity of artisanal mining, and the various factors that are deterministic to health and safety in these communities, requires a multipronged intervention.

KEY MESSAGES

1. ASM is a complex ecosystem in which workplace hazards and risks can have detrimental consequences on the immediate and long-term burden of disease of these communities.
2. There are several hazards faced by artisanal miners in the Kimberley area, including physical, respiratory, and psychological hazards.
3. The occupational health and safety challenges in ASM are similar to those in LSM.

DECLARATION

The authors declare that this is their own work; all the sources used in this paper have been duly acknowledged and there are no conflicts of interest.

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AUTHOR CONTRIBUTIONS

Conception and design of the study: AR, JA-S
Data acquisition: AR, JA-S
Data analysis: AR, JA-S
Interpretation of the data: AR, JA-S
Drafting of paper: AR
Critical revision of the paper: AR, JA-S

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