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Safety aspects and recommendations for surface artisanal mining

by S.M. Rupprecht*

Synopsis

Artisanal mining is a significant industry in sub-Saharan Africa, accounting anywhere from 2% to 20% of a country's gross domestic products (GDP). Safety concerns in artisanal mining are often overlooked due to the nature of the business, which is largely a subsistence occupation. This paper presents some of the basic risks observed in surface artisanal mining operations and provides basic safety recommendations for artisanal mining operators to follow to prevent serious accidents or fatalities. The most frequently cited causes of serious accidents are subsidence of highwalls, misuse of explosives, lack of knowledge and training, and obsolete and poorly maintained equipment.

Keywords

surface mining, safety, artisanal mining, small-scale mining.

General nature of artisanal mining

The artisanal mining sector is largely informal, labour-intensive utilizing little or no machinery, yet provides an essential livelihood (directly or indirectly) for many participants, as well as forming an important source of cash into many communities. Surface mining hazards include highwall collapse or slumping, rockfalls from pit sidewalls, mudrushes while lashing rock, falls into unprotected pits, and falls from pit benches. Mining is labour-intensive and is generally conducted utilizing hand digging methods *e.g.* shovels or chisels. Artisanal mining varies from site to site, but is generally well structured despite its informality. Artisanal mining sites generally have some inherent management structure and extraction activities are often organized through teams of about 10 to 20 diggers (Figure 1) who cooperate in one pit; and who are generally accompanied by supporting crews *e.g.* transporters, rock crushers, mineral washers, and waste disposal crews.

Artisanal mining is generally more dangerous than large-scale modern mining operations, as artisanal operations are subsistence activities. The focus is on more immediate concerns than the long-term consequences of the activities. When miners have no other source of income, they will usually find ways to evade controls and carry on working. It must be noted that the introduction of machinery is far beyond the economic reach of most artisanal miners; and therefore there is a general tendency for workers to revert to more labour-intensive and thus more risky mining methods.

The capacity of government to oversee the artisanal mining sector is limited due to the inability to cover the area under their responsibility, shortage of personnel, and lack of capacity and technical knowledge. Artisanal miners employ a wide range of skills and abilities to exploit the varied deposits, but in general there is a low level of understanding of safe and compliant mining.

Three types of artisanal mining operations typically exist: surface 'pit' mines, underground workings, and alluvial mining operations. This paper focuses on the safety issues around artisanal surface mining and looks at providing practical guidelines that should be considered when conducting artisanal or small-scale mining. The objective of this paper is to propose a safe and realistic approach to improving surface mining conditions and increase health and safety awareness among independent operator, in a manner appropriate to local circumstances.

Safety issues

Artisanal miners often operate in hazardous working conditions. There are several major health risks associated with artisanal mining:

- Exposure to dust
- Exposure to mercury or other chemicals
- Effects of noise and vibration
- Effects of overexertion and inappropriate equipment.

* *University of Johannesburg, Johannesburg, South Africa.*

Figure 1—Typical example of artisanal mining in Central Africa

Figure 2—Rockfall in an artisanal open pit, Central Africa

Many accidents occur in artisanal mining. The five most frequently cited causes are as follows:

- Rockfalls (Figure 2), subsidence, and tunnel collapses
- Lack of ventilation
- Misuse of explosives
- Lack of knowledge and training
- Obsolete and poorly maintained equipment.

The following paragraphs describe some of the good and bad practices observed during various site visits. Figure 3 represent typical examples of artisanal surface mining operations in Central Africa where water is often employed to saturate the soil and tunnels dug into the highwall facilitate the collapse of the highwall. Although government regulations require benching to be conducted, it is obvious that no attempt is made to do so.

Figure 4 demonstrates unsafe surface mining practices with a mining crew working adjacent to the edge of the highwall. In this case, workers are exposed to the hazards of falling over the edge or slumping of the highwall. Figure 5 demonstrates the use of benching to improve mining conditions.

Figure 6 and Figure 7 provide examples of benching in artisanal mining. In these examples a dozer was used to establish benches at the top of the mining pit. Figures 8, 9, and 10 illustrate undermining of the highwall. The mining areas in Figure 9 and Figure 10 have subsequently collapsed. Figure 11 illustrates a severe highwall failure in which the entire mining face collapsed.

Surface mining

The biggest concern with surface mining is the widespread practice of undercutting steep pit walls to follow mineralized veins without a stable highwall or bench. Surface mining should be conducted utilizing bench mining (terraced) methods. Access to the pit floor is frequently treacherous,

Figure 3—Typical highwall collapse

Figure 4—Mining close to edge of highwall

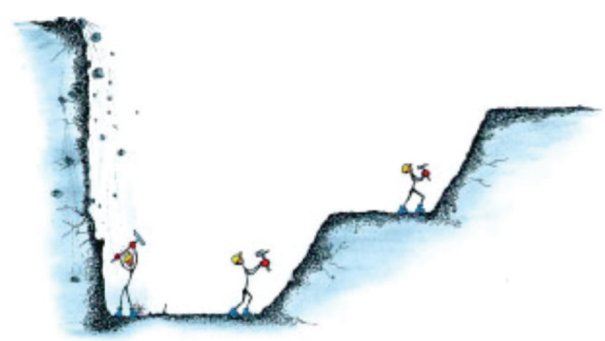

Figure 5—Sketch illustrating poor and good mining practices (Walle and Jennings, 2001)

Figure 6—An example of benching

Figure 7—Mining activities on bench

Figure 8—A schematic of unsafe mining under a brow (Walle and Jennings, 2001)

Figure 9—An example of creating a brow

Figure 10—An example of undermining into a highwall

Figure 11—Example of a highwall collapse

with miners often carrying heavy loads (ore and/or concentrate). Also mining may take place adjacent to stronger, more competent rock, creating highwalls that contain unstable blocks. As a general rule, workers should not work closer to a highwall than 25% of the height of the highwall (the 'drop zone'). For example a bench height of 5 m would require a drop zone of 1.25 m. Note there may be other considerations for increase the size of this drop zone when applying highwalls above 5 m, for example considerations regarding shear plane failure or bench angles.

The best way to remove this risk is through bench mining. This can be done either by hand or by machinery such as an excavator or dozer. The bench should be wide enough to prevent rocks from dislodging from the highwall face and rolling beyond the bench and into the pit, and to enable persons or machinery to operate safely without the risk of going over the edge.

Benches perform two important functions. Firstly, they impart stability to a highwall. Where a highwall contains geological discontinuities such as joint sets, faults, slips, bedding planes, *etc.*, benches can increase the stability of the highwall. Secondly, where slumping of the highwall is a problem, benches can prevent materials from falling into the pit (Figure 12). The impact of falling rock is illustrated by the following considerations.

A rock 75 mm in diameter (1.2 kg weight) falling some 33 m impacts with a force of approximately 450 kg. A 150 mm rock (9 kg) falling over the same height would result in an impact force of over 3600 kg (3.6 t). A 300 mm rock (78 kg) over a 20 m height would result in a force of 5800 kg (5.8 t).

General safety issues

The following general safety issues should be seen as 'quick wins', which can be used to improve and communicate the importance of safety within the artisanal mining community (Figure 13). Notably, it is not recommended that all personal protective equipment (PPE) is required for all tasks; rather key areas should be identified for the implementation of the appropriate PPE.

- First aid equipment to be readily available and visible
- Introduction of sanitation facilities within the mining concession areas
- Requiring that PPE (Figure 14 and Figure 15) be worn for the appropriate task being undertaken:
  - Hard hats for underground workings
  - Safety boots for all mining operations
  - Eye protection for rock breaking duties
  - Gloves when handling rocks and metal objects
  - Dust masks for dusty areas.
- General training to identify key risks in mining, including the use of suitable visual materials to reinforce the identification of risk
- Conducting of safety checks before the commencement of work and the use of a central reporting system to highlight incidents or problems.

One way to reduce the risks associated with artisanal mining is to introduce alternative methods and/or equipment. However, for artisanal miners to adopt a new mining method or process there must be immediate and obvious financial or timesaving benefits. Miners must be able to understand and trust the new methodology/technology. It is important that any technology introduced is also reviewed in regard to safety, as often attempts to mitigate an existing risk can introduce a more serious risk.

The implementation of mining standards on artisanal mining operations must be viewed in context of the working environment. Artisanal mining is currently a subsistence activity for most participants, thus safety standards may be seen as interference and having an adverse effect on workers'

Figure 12—Potential accident situation due to falling rocks (left), and large rocks fallen from highwall

Figure 13—Artisanal mining without PPE

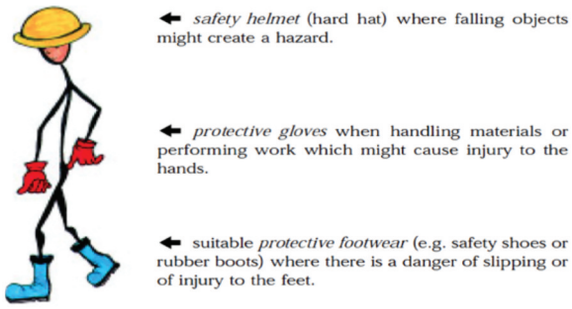

Figure 14—Recommended personal protective equipment (PPE) (Walle and Jennings, 2001)

Figure 15—Artisanal miners utilizing appropriate PPE

income. Therefore, it is critical that mine operators realize the importance of safety and seeking to balance productivity with the need to improve working conditions. Standards must be relevant, and the introduction of safety measures should be seen as a process requiring buy-in from a number of stakeholders; starting with the miners themselves and including the mine owners if applicable, governmental agencies, the community, and mineral buyers. Appropriate minimum standards should be identified and progressive improvement in working standards established by all parties concerned. The implementation of mine health and safety standards should be viewed as a process with immediate, short-, medium-, and long-term goals.

Artisanal miners must be able to understand the benefit of the proposed safety standards in order for changes to take place. Initial standards must be realistic and achievable so that immediate results can be seen, thereby encouraging the miners to commit to and remain engaged in the process. Unrealistic goals will result in noncompliance and failure. To some extent mine operators will be required to enforce basic safety standards. Failure to comply should result in corrective action being taken by the government (government agencies) and the threat of loss or suspension of the mining right. Fines or other sanctions should be used as further motivation to facilitate change.

It has been demonstrated that artisanal miners are willing to adopt safety standards and better practices. Rewarding of positive behaviour should be considered so as to create a positive response and 'jump-start' the safety process. Rewards could be in the form of salary increases, or increases in the purchase price of the metal/concentrate, linked to general safety compliance and performance. All participants must understand that the transformation required will incur costs, which need to be shared between owner, mineral buyer, and government.

Based on a daily rate of US$5 and an excavation rate of 5 m^3 per 10-hour shift, manual benching is not capital-intensive, requiring approximately US$6000 per month per worker. However, the introduction of this method will initially require strict supervision to ensure that the desired mining sequence is achieved. Also, the change in mining method will most likely result in an increase in payment to the mineworkers, as manual labour requirements increase with manual benching. Together with the introduction of bench mining, standards must be put in place to ensure that workers adhere to basic safety and health principles.

Training

Training should be based on 'practical theory' combined with the practical application of the theory, *i.e.* 'the doing'. The following comments are relevant to establishing a training programme for artisanal miners and associated parties.

- Training should focus on practical work rather than just demonstrations
- The training scheme should remunerate attendees to the equivalent to what they could earn in full-time employment,
- Mine operators and government officials should be encouraged to attend short courses dealing with a wide range of issues, including:
  - Minimum standards in regard to health and safety
  - Demonstrations, ideally by equipment manufacturers' representatives, of equipment for modest increases in mechanization of mines,
  - Training in the area of finance (techno/evaluations). The principle would be to develop an understanding of the benefits of re-investing into a mine, *i.e.* geological understanding of mineral resources, mine planning, mining and processing of the ore, and financial management are the foundation of an operation that should assist in promoting growth and improved profits

Figure 16—Artisanal miners

- Mine operators should be assisted to understand the basic concepts of surface mining
- Current working mines should be assisted to become showcases of best practice, so that other miners can observe the actual implementation of the theory. These should not be training centres as such, but operating mines that are implementing best mining practices
- A core technical team should be established to provide support and assist miners in improving safety and productivity. Initially, the cost of the team may need to be supported by a funding mechanism (*e.g.* governmental agencies/departments, non-governmental organizations (NGOs), purchasers, *etc.*) but in the medium to long term, the costs of this technical support should be funded by mine operators as a percentage of earnings from the sale of concentrate
- Governmental agencies/departments, NGOs, and mineral purchasers should assist in the promotion of training programmes, *i.e.* short courses and best practice mines so that artisanal miners, supervisors, owners, and other associates mining can immediately improve their technical skills in terms of safety and mining.

Conclusions and recommendations

Artisanal mining operations are often unsafe and do not adhere to best practice. It is recommended that bench (terrace) mining be undertaken to improve pit highwall conditions and general safety in surface mining. Bench mining can be undertaken utilizing picks and shovels and wheelbarrows, with the potential to increase productivity through the introduction of mechanization. Bench mining utilizing picks and shovels should be the method of choice for remote operations or concessions that have a limited life. Mechanized mining utilizing dozers or excavators is currently being practiced by some mines, but is applied only intermittently and unsystematically, and thus does not eliminate risk of highwall instability.

Training by means of short courses and practical sessions should help to improve mining standards, conditions, and productivity. It is recommended that best practice mine sites be established and used to promote safe mining practices.

References

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