Safety aspects and recommendations for surface artisanal mining

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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 risks commonly observed in surface artisanal mining operations and provides basic safety recommendations for operators to follow to prevent serious accidents or fatalities. The five most frequently cited causes of serious accidents are rockfalls and collapses, lack of ventilation, 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 constituting an important source of cash for many communities. Surface mining hazards include highwall collapse or slumping, rockfalls from pit sidewalls, mudrushes while lashing rock, falling into unprotected pits, and falling from pit benches. Artisanal mining is labour-intensive and is generally conducted utilizing manual digging methods *e.g.* shovels or hand 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 the extraction itself is often organized through teams of about 10 to 20 diggers (Figure 1) who co-operate in one pit; and they are generally accompanied by supporting crews *e.g.* transporters, rock crushers, mineral washers, and waste disposal crews.

![Figure 1. A typical example of artisanal mining in central Africa](image)

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 often 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 and ineffective due to the inability to cover the area under their responsibility, shortage of personnel, and a lack of capacity and technical knowledge. A wide range of skills and abilities is currently used 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 mining, and alluvial mining. 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 is to find a safe and realistic approach to improving surface mining conditions, raising independent operators’ awareness of health and safety issues, 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.

In addition, there are many accidents 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.

Figure 2. A rockfall in an artisanal open pit
Figures 3–11 illustrate some of the good and bad practices observed from various site visits. Figure 3 represents 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 to facilitate collapse of the highwall. Although government regulations require benching to be conducted it is obvious that no attempt is made to do so.

Figure 3. Typical artisanal mining and highwall collapse

Figure 4 shows 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 4. Mining close to edge of highwall
Figure 5. Sketch of poor and good mining practices (Walle and Jennings, 2001)

Figure 6 and Figure 7 provide examples of benching in artisanal mining. In these examples, a dozer was used to establish benching 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.

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
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 often treacherous, with miners frequently 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 within 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 that there may be other considerations that would warrant increasing this drop zone area in the case of highwalls above 5 m; for example, 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 dislodged from the highwall face from rolling beyond the bench and into the pit. The width should also be sufficiently so that persons or machinery can operate safely during excavation of the bench, without the risk of going over the edge.

Benches perform two important functions. Firstly, they provide stability to a highwall. Where a highwall contains geological discontinuities i.e. joint sets, faults, slips, bedding planes, etc., providing benches can increase the stability of the highwall. Secondly, where slumping of the highwall is a problem, benches can be used to keep materials from falling into the pit (Figure 12). As a means to gauge the impact of falling rock, consider the following. A 75 mm rock (1.2 kg weight) falling some 33 m yields a force of impact of approximately 450 kg. A 150 mm rock (9 kg) 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 the use of 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
  - Hand 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 aids to reinforce the identification of risk
- Conducting of safety checks before the start of work, and the use of a central reporting system to highlight incidents or problems.

Figure 12. Potential accident hazard from falling rocks, and large rocks fallen from highwall

Figure 13. An example of artisanal mining without PPE

Figure 14 and Figure 15. Examples of PPE worn by miners.
One way to reduce the risks associated with artisanal mining is to introduce alternative methods and/or equipment. However, for artisanal miners to take up 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 whatever technology is introduced is also reviewed in regard to safety, as often one may introduce a larger risk while attempting to mitigate the existing risk.

The implementation of mining standards in artisanal mining operations must be viewed in the context of the working environment. Artisanal mining is currently subsistence work for most participants, thus safety standards may be seen as interference and having a negative impact on a workers’ income. Therefore, it is critical that mine operators realize the importance of safety and seek a balance between productivity and 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-term, as well as medium- and long-term goals.

Artisanal miners must be able to understand the benefit of the proposed safety standards in order for change 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 action 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 positive behaviour should be considered to jump-start the safety process so as to create a positive response. This could
take the form of an increase in salary, or linking the purchase price of the metal/concentrate to general safety compliance and performance. It must be understood by all participants that the transformation required will incur costs. The cost of such action needs 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 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. Along with the introduction of bench mining, standards must be put in place to ensure that workers adhere to basic safety and health principles.

Figure 16. Artisanal miners

Training

Training should be based on ‘practical theory’ combined with the practical application of the theory, i.e. ‘the doing’. The following comments are made regarding establishing a training programme for artisanal miners and other parties associated with artisanal mining:

• Training should focus on ‘the doing’ rather than just demonstrations
• When training artisanal miners, the training scheme should renumerate attendees to the equivalent of 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 the following:
  • 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 finances (techno/evaluations). The principle would be to develop the understanding of the benefits of re-investing in 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.

Assisting mine operators to understand the basic concepts of surface mining

• Current working places should be assisted in becoming mines 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 to provide support and assist miners in improving safety and productivity. Initially, the cost of the teams 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 of artisanal 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 by pick-and-shovel should be the method of choice for remote operations or concessions that have a limited life. Mechanized mining with dozers or excavators is currently being applied by some mines, but the machinery is used intermittently, and if not systematically applied it still leaves the risk of highwall instability.

Training combined with short courses and practical session 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.

Reference