Is there an Alternative to Mercury use by Small Scale Gold Miners?

In Zimbabwe elemental mercury is used in artisanal and small-scale gold mining. Mercury is mixed with gold-containing materials, resulting in the formation of the mercury-gold amalgam which is then heated, vaporizing the mercury to obtain the gold. This process is very dangerous and can lead to significant mercury exposure with serious environmental and health risks. The Minamata Convention on Mercury, aims to reduce mercury pollution, particularly from artisanal and small-scale gold mining sector. The convention calls for parties to reduce, and where feasible eliminate mercury use within the gold mining sector. Traditionally, the use of mercury is one of the most accepted methods of recovering gold. In view of the dangers associated with mercury, there is need to explore alternatives which are safe and economically viable. Mercury-free techniques are safer for miners, their families, local communities and the nation at large. They may also help miners market their gold at higher prices if they bring the concept of "green gold". Below are some of the techniques that can be embraced.

Concentration Methods

Concentration methods thrive on increasing the amount of gold in ore or sediment, by selectively removing lighter materials (gangue). If employed effectively, concentration methods can eliminate or greatly reduce the quantity of mercury in gold recovery.

Prior to concentration, ore must be crushed or milled to liberate gold particles from rock and to increase the surface area. Concentration works best when particle size of the milled material or sediment is relatively consistent, so that most particles are of similar size. The use of screens or sieves can be employed to get a consistent particle size. Once the gold-containing material has the appropriate particle size, one (or several) of the methods described below can be employed to concentrate gold bearing material:

Most concentration methods rely on the high density of gold relative to other minerals in ore or alluvium mixture. These are referred to as gravity methods. Magnetic or chemical properties can also be exploited to enhance concentration.

Due to spatial and temporal differences as well as the uniqueness in mining operations concentration methods must be selected carefully. Factors such as the type of ore or sediment, other minerals present, gold particle size, and the availability of water and electricity should be considered when selecting a particular method.

Gravity Concentration Methods

Panning

The panning process uses water to separate heavy gold particles from lighter ones within a medium sized pan. In this process ore thought to contain gold is placed in a wide, curved pan along with water. The miner moves the pan in a series of circular motions designed to remove lighter sediments. The high density of gold allows it to settle on the bottom of the pan as lighter

material is removed along with water. The process is repeated for some time until gold is exposed on the bottom of the pan for the miner to recover.

Panning is effective when gold is relatively coarse and well liberated. All factors being constant, panning can produce high grade concentrates or even liberated gold. Then miners can employ gold recovery methods such as direct smelting (described below), although many panning operations lead to directly recoverable gold.

Panning is a low cost technology of gravity concentration that requires time and skill to be effective. One of the major drawbacks to panning is that miners must pan small amounts of concentrate. Therefore, panning is often done after other methods of gravity concentration such as sluicing have completed.

Sluicing

Sluices use water to wash ore or alluvium down a series of angled platforms. As water washes sediment down a sluice, gold particles tend to sink and are captured by material covering the bottom of the sluice, often carpets. Sluices are usually inclined at 5 to 15 degree angle. As moving water travels down a sluice, it generates greater force and keeps gold particles from sinking easily. For this reason most gold is captured at the beginning of the sluice. Carpets or other capturing devices on the bottom of sluices can be removed and washed in a bucket to remove the captured gold.

The design of a sluice can lead to higher gold recovery if the force of the water traveling through the sluice is greatly decreased. Also a series of rifles can contribute towards the management of flow to improve gold recovery. The use of a zigzag sluice can also achieve the same by creating a drop between the first and second platform that disrupts the velocity of the water as it moves down the sluice. Another way of improving the zig zag sluice is to have a combination of two sluice surfaces. The first is tilted at a steeper angle then the second, decreasing the velocity of the water as it hits the second sluice, increasing gold recovery.

Water supply is a prerequisite to have a functioning sluice operation. This can be done with piping, drums, buckets, or natural flowing water bodies. A constant flow will be better than a bucket-driven flow. Sluices are good at concentrating large amounts of ore and sediment in a relatively short time but often do not yield concentrates with high amounts of gold. The resulting concentrate must usually undergo further methods of concentration, such as panning.

Shaking Tables

Shaking tables are elevated tables tilted to one side with raised ridges running horizontally down their length. Crushed ore or sediment feed and water are released at one end of the table. The water washes the crushed ore down the table. As the material is washed down the table, specialized grooves trap gold and direct it to collection points on the side of the table as lighter minerals are washed away. Concurrently, the table is continually shaken by a motor to agitate the material and aid in the separation of gold.

Shaking tables are effective and can concentrate large amounts of ore at a time, considering high grade concentrates and liberated gold, but they are also relatively expensive and require some experience to operate.

Spiral Concentrators

The term spiral concentrator refers to specialized pans tilted on an angle with spiralled grooves. The spiral grooves in the pan lead toward the centre where a hole is connected to a container to catch material.

The pan is rotted continually using a pan as concentrate is fed onto the pan by an operator. In most designs a pipe extending horizontally across the pan sprays water along the surface of the pan as the concentrator spins. The water washes lighter particles down the spiral concentrator into a bucket while denser particles, including gold, are carried by the spiral grooves toward the hole in the centre of the concentrator. The process is repeated several times until the operator is left with a high grade concentrate, and often liberated gold.

Vortex Concentrators

Vortex concentrators makes use of a rotating flow of water to separate lighter materials from a concentrate and remove them via a raised drain hole. A vortex concentrator is a 'circular tub' with water input on the side of the tub and a raised drain in the centre. The said circular tub is filled with water until it reaches the level of the drain hole. The concentrate is then added in a thin layer around the bottom of the bowl. Following this, water is then pumped into the side input, creating a rotating vortex of water that drains in the centre. The created vortex pulls lighter material up from the bottom of the bowl and out through the drain hole. Gold because of its high density remains on the bottom of the tub for collection. The methods requires expertise in that there is need to monitor the amount of water flow going into the tub. If it is too great the velocity of the water will carry gold particles out of bowl and this will lead to losses of gold.

Centrifuges

By definition, a centrifuge is a vessel that rotates about a central point. Its wide application has been related to the separation of materials in a mixture by density. In a bid to apply the principle to gold processing, concentrate is fed into the centrifuge through an inlet pipe at the top of the centrifuge in a slurry of around 60-75% water and 40-35% solids. The fed material collects in a vessel in the centre of the machine where high speed rotation creates a force that moves the material up the sides of the vessel's walls. As the materials are pushed up the sides of the bowl's wall, denser material like gold is caught in ridges while lighter material is ejected from the centrifuge.

Other Concentration Methods

Magnets

The use of magnets can be employed to remove magnetic minerals such as magnetite from the concentrate. Magnets can be used after and/or in conjunction with other methods of concentration. One technique for extracting magnetic minerals is to place hand held magnets on the bottom of a pan containing dried concentrate to separate metallic from non-metallic material. It is critical to take due care to avoid losing gold particles during the separation. The use of a piece of paper so that the minerals attracted to the surface of the paper can be easily removed.

Flotation

The flotation process is usually used by large scale miners but can also be adopted in small scale operations. The process is best for processing complex ore types, especially ores that are difficult to process using gravity methods. When doing flotation, a mixture of slurry and frothing agents are added into a flotation machine. A tube releases air into the tank of the machine and an agitator creates air bubbles at the bottom of the tank.

Minerals that are hydrophilic, such as gold, attach to the bubbles' surface and are brought up to the top of the tank. Other minerals fall to the bottom of the tank and are discarded as tailings. Bubbles containing gold and other hydrophilic minerals accumulate at the top of the water level as froth. This froth is then scraped off to create a concentrate of gold and other hydrophilic minerals. Flotation creates high quality concentrates and is good at capturing fine gold.

Gold Recovery

Direct Smelting

The methods briefly explained above can yield a concentrate with a large proportion of gold comparative to other materials. Nevertheless, there is need separate the gold from the other remaining minerals before it can be sold. Methods like direct smelting can then be employed to recover gold. When using direct smelting, the high-grade concentrate is heated until the gold melts. The liquid is then cooled to form solid gold dore, a semi pure gold alloy, that can reach upwards of 95% purity.

Chemical Leaching

Chemical leaching makes use of the chemical properties of gold to leach it from the ore, concentrate, or tailings. Leaching is commonly used in large scale mining operations but has been increasingly adopted in small scale mining because of its high gold recovery rate and low cost. For best results when using chemical leaching there is need to use a combination of pre-concentration and mill leaching, as they lead to the least amount of waste, a short processing time for miners, and high gold recoveries. Some of the chemicals used for leaching are toxic e.g. cyanide compounds. When chemical leaching is employed, it is important for miners to handle the chemicals in a sound manner and to ensure that they use appropriate personal protective clothing to avoid health and environmental concerns.

Cyanide is highly toxic and great precautions must be taken when handling it. However, in contrast to mercury, cyanide is does not persist in the environment. Cyanide leaching should not be done on tailings where mercury is present because cyanide will from a soluble mercury-cyanide complex, mobilising mercury to great distances.