Technologies for Small Scale Primary Gold Mining

traditional vs. alternative processing methods



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7 days old pictures from Indonesia





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"At the end of the day this is the small scale miners aim"



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Content:

- 1. Environmental impacts and mercury emissions by using traditional mining and processing methods
- 2. Advantages and Disadvantages of traditional methods
- 3. Tasks for tomorrow and for clean gold production
 - economical and technical criteria
 - environmental criteria
 - social and cultural criteria
- 4. Technical solutions and possibilities
- 5. Conclusions

- 1. Environmental impacts by using traditional mining and processing
 - -sulphide emissions
 - -heavy metals emissions
 - -emissions of solids (coarse, fine to rivers)
 - cyanide emissions
 - -deficient tailings management
 - -devastation of land, riverbanks; erosion
 - deforestation

1. Mercury emission in the traditional primary ore processing

- pre-concentration and concentration in open circuits (whole ore amalgamation)
 - use of mercury in sluice-boxes
 - use of mercury in mills (ball mills, Chilean mills, stone mills)
 - use of amalgam plates
 - use of mercury in centrifugal concentrators
- in amalgamation tailings
- burning of amalgam without retort
- losses through spilling

mercury is lost as: floured mercury, amalgam flocs, fine amalgam, partially amalgamated gold, vapor

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Mercury emissions in traditional gold ore processing (typical average values)

emissions through (pre-)concentration in open circuits

emissions in amalgamation tailings

emissions through separation Au-Hg (generally burning of amalgam) 1- 40kg Hg/kg recovered Au

0,01-1kg Hg/kg recovered Au

0,5 – 2 kg Hg/kg recovered Au

(values are depending on the used method, the type of ore, the experience of the operators, etc.)

2. Disadvantages of traditional methods

- low recovery (in some cases)
- negative environmental impacts (mostly)
- industrial safety not existent (mostly)
- high demand and costs for mercury and other reagents like cyanide
- hard manual work (mostly)
- limitation to high grade ores (in many cases)
- no recovery of valuable by-products (often)
- processes not really made for the deposit but copied from the neighbor
- limited capacity (manual mining and processing)

2. Advantages of traditional methods

- known and accepted processes (sometimes since centuries)
- simple processes (handling and maintenance)
- low-cost, self made or locally produced equipment and machines
- processes are adapted to the local working structure, to the cultural and social environment
- processes are adapted to the existing marketing system
- little mechanization gives work to many uneducated people

It is often better, to improve the traditional methods in a mining area than to introduce new, unknown processes

3. Tasks for tomorrow or the Requirements for a clean technology in small scale gold mining (1)

Technical-economical criteria:

- the technology must be technically efficient (more than the traditional methods)
- low in investment and operating costs
- the equipment, if possible, needs to be manufactured locally
- simple and safe handling and maintenance (also by less qualified personnel)
- long life span
- can be integrated into the existing processes

Requirements for a clean technology in small scale gold mining (2)

Environmental criteria:

- low actual environmental impact
- no environmental "time bomb"
- use of new process helps to reduce conflicts with neighbors (e.g. farmers)

Requirements for a clean technology in small scale gold mining (3) Social and cultural criteria

- the new technique approved by and proved together with the miners
- personal to handle the process is available (quality and quantity)
- the new process does not interfere with religion, habits, superstitions
- the new process does not create problems in the marketing of the products
- the new process does not cause problems between miners and other actors (concession owners, gold buyers, equipment and consumable suppliers, etc.)

In simple words:

What are the most important reasons for the small miners to use cleaner technologies ?

- because they give them more gold with less effort!
- because they avoid confrontations with neighbors (farmers, fishermen, etc.)
- because they are necessary to get an environmental permit and legalize the operation
- because they listen to their women

Before coming to the technical part:

To improve the environmental situation in small scale mining, by introducing alternative technologies

individual and adapted solutions for each mine/deposit/operation have to be found

,,one size fits all" - solutions do not exist !

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2. Technical solutions and possibilities for clean or cleaner gold processing

Crushing and Grinding

Jaw Crusher

capacity: 0-1000t/h

- can be produced locally
- simple operation and maintenance
- is necessary before a ball mill
- improves capacity for other mills



Ball mill

Advantages:

- product size can be very fine
 (e.g. for flotation, < 150µm)
- works with very hard material
- can be built locally (in experienced workshops)
- saves coarse gold inside

Disadvantages:

- feed size <20mm (needs crusher)
- danger of over milling
- mills gold to very thin flakes,
- stains the gold with iron
- not good for batch processing
- in non-mining countries, balls difficult to find
- high investment costs compared to capacity



Hammer mill

capacity (used with water) in SSM: 0,3 to 2,5t/h

Advantages:

- can be produced locally
- feed size up to 60 mm
- good for batch processing
- light weight
- simple operation and maintenance
- low cost compared to capacity

Disadvantages:

- not for very fine product size (usually until p_{80} of about 300µm)
- not for very hard material (chalcedonic quartz veins)
- relatively high operation costs (hammers)



Screening and Classifying

Grizzlies, non moved screens

examples for use:

-removes fine material before a crusher



Vibrating screens

examples for use:

- removes coarse barren oversize before a sluice



Spiral classifier

examples for use:

-in milling circuits, in combination with ball mills

-to dewater sand tailings (for dry depositing)



Concentration and Separation

Sluice box (alluvial), Strake or Blanket Table (primary)

Advantages:

- very low cost
- high capacity (alluvial mining)
- local production
- no motor no moving parts
- easy operation



- good recovery even for fine gold (if properly built and operated)
- high enrichment ratio
- good for cleaning of amalgamation tailings

Disadvantages:

- needs much manual work, security problem
- does not completely recover sulfides in primary mining
- discontinuous process



Test Sluice Box (left: turbulent, right: laminar)

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Examples for the use of sluice boxes (1)



Examples for the use of sluice boxes/strakes (2)







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Sluicebox for cleaning alluvial pre-concentrate

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Jig (mechanic)

Advantages:

- can be produced locally
- high capacity (in alluvial mining)
- low cost
- recovers flattened gold after ball mills
- wide size range of feed and products

Disadvantages:

- relatively difficult set-up and operation
- needs motor
- needs water



Examples for the use of Jigs



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Shaking table

Advantages:

- recovery of various products (concentrate, middlings, tailings)
- visible process, good control
- flexibility
- good gold and sulfide recovery
- relative easy operation
- high enrichment factor
- for cleaning amalgamation tailings
- continuous process
- local production posssible

Disadvantages:

- high cost regarding its limited capacity
 - (principal use as secondary enrichment/cleaner step)
- needs very steady feed and constant supervision
- needs motor



Examples for the use of shaking tables



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Spiral concentrators (spirals)

Advantages:

- recovery of various products (concentrate, middlings, tailings)
- material visible during the process
- good recovery of gold and sulfides
- easy operation
- continuos process
- high capacity for small primary gold mining (50t/d for a single start spiral)
- no motor no moving parts

Disadvantages:

- needs material screened to minus 2mm
- low enrichment factor (typical pre-concentration device)
- needs ca. 4 m altitude from feed to discharge (with pump or natural)
- not suitable for local production



Examples for the use of spirals





Centrifugal Concentrators (Falcon, Knelson), batch type

Advantages:

- size/capacity from small to large
- good recovery (for example, for fine gold $< 30\mu m$, better than any other equipment)
- very high enrichment factor (can work without secondary upgrading)
- good for cleaning amalgamation tailings
- high security against theft

Disadvantages:

- needs clean and pressure water
- limited recovery of sulfides
- difficult handling
- needs electrical motor
- needs narrow classified feed
- local production not possible
- spare-parts and maintenance problem
- high investment costs

FALCON

A highly effective, but not really a "small scale miners proof " piece of equipment!

Examples for the use of centrifugal concentrators



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Amalgamation



"Burning" of amalgam

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Final aim must be, to eliminate completely the use of mercury in small scale mining.

If it is not possible to eliminate the amalgamation in small scale mining eliminate the amalgamation in small scale mining, it has to be

- controlled
- optimized and

- restricted to the amalgamation of concentrates

Mechanized Amalgamation



Amalgamation Drum



Amalgamation Mixer

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If the main mercury emissions are:

- through its use in open concentration circuits or

- through burning of amalgam

these are the main fields of intervention

The most effective way to reduce mercury emissions in open concentration circuits is the improvement of gravity concentration

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Reducing mercury emissions through efficient gravity concentration

Gravity concentration is the most appropriate method for small scale gold mining because of

- no reagents are needed
- simple operation (exception: jigs and centrifuges)
- low investment costs
- other valuable minerals can be recovered (sulfides, cassiterite, diamonds)
- great variety of types and size of machines available
- process water can be recycled easily after solids removal

Optimization of the amalgamation of concentrates

objective: - high recovery

- low production of floured mercury
- low content of gold and mercury in amalgamation tailings

realized through:

- use of appropriate equipment (barrels, cones, mixers or manually)
- perfect amalgamation time
- use of reagents to improve amalgamation process

Methods for the separation of gold from amalgam recovering the mercury

- small mobile retorts

- stationary retorts

Small Retorts (mobile retorts)

Advantages:

- high mercury recovery (98%) in liquid form
- light and mobile equipment
- relatively easy handling
- local production possible
- old mercury can be cleaned
- -low cost (from local production)



Large retorts (stationary)

Large stationary retorts have a air suction system driven by a ventilator. The burning of the amalgam takes place using torches, the gold is visible during the process

Advantages:

- amalgam and gold visible during the process
- gold comes out clean and shiny
- short process time
- amount of amalgam does not matter



Disadvantages large stationary retorts:

- heavy, large stationary equipment
- needs electric or gasoline motor for the ventilator
- recovery considerably lower than in small closed retorts (90%)
- relative high investment costs
- maintenance (mainly motor)

Alternatives for the amalgamation of gold bearing concentrates (examples)

- a) direct smelting
- b) cyanide leaching
- c) leaching with other reagents (chrorine, bromine, etc.)
- d) gold/oil aglomeration

These processes are difficult to implement in small scale mining, due to their

- need for highly enriched concentrates (a, d)
- technical comlexity (c, d, e)
- high costs (c, d)
- health, safety and environmental problems (b, c, d)
- slow processes (b, c)

Cyanide leaching

The use of cyanide is an alternative to mercury in small scale gold mining.
But:

- it makes absolutely no sense to combine amalgamation and cyanidation

- cyanide leaching of amalgamated material is producing dissolved mercury

- cyanide is a highly toxic, deadly reagent. Maximum attention has to be given to proper handling and environmental protection

Cyanide leaching is in a process of auto-diffusion in many small gold mining areas. It is most important to start now with education of the miners to guide them from the beginning

Cyanide leaching



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Cyanide leaching methods used in small scale mining

In small scale mining, mainly two methods are used

- percolation leaching (vat leaching) of sands
- agitation leaching of fines

Advantages:

- good recovery of gold and silver
- usable for gravity concentration tailings
- relatively simple process

Disadvantages:

- mercury and heavy metals in the material are partially dissolved and emitted in water and tailings
- emissions of cyanide and its components
- safety problems
- in small scale mining, rarely correct residue water treatment and tailings deposition are found



Agitation leaching

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General Aspects of the Implementation of Technical and Environmental Measures in Small Scale Mining

- the technical and environmental measures have to be adapted and tested together with the miners and not over and has ro be approved by them
- the proposed techniques have o be simple, low-cost, easy to operate and maintain
- it is easier and more efficient, to optimize existing traditional processes than to import and introduce new processes
- it is absolutely necessary to guarantee good training and a long-term follow-up

Conclusions:

It is possible to introduce "cleaner" technologies to small scale miners

Each case is different, there are many possible solutions

These technologies exist, there is not much need for investigations and/or studies or pilot work

Massive campaigns to spread out the knowledge and to introduce and implement the cleaner technologies are needed

and they are needed now

Thank you

Terima kasih

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