



Global Mercury Project



Project EGI/LO/01/G34:
Removal of Barriers to Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies

Retorts: Many options and many barriers *(searching for sustainable solutions)*

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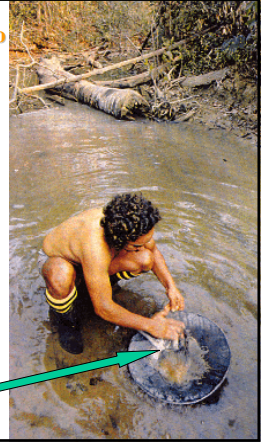
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Artisanal Miners use mercury to amalgamate gold usually coarser than 74 µm.

Why ASM use Hg?

1. Easy to be used
2. Cheap
3. Very accessible
4. Miners are not aware of the danger of Hg

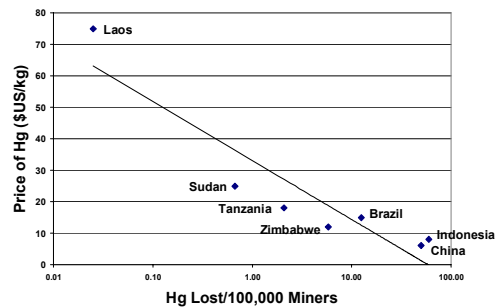
Mercury is added to the pan



Hg is Easy to Be Used

- Amalgamation is simple and effective to trap gold particles coarser than 0.074 mm; if used correctly > 90% of gold in gravity concentrates is trapped by Hg
- Hg forms an amalgam with most metals except iron and platinum.
- Au can combine with Hg to form a wide range of compounds from AuHg₂ to Au₈Hg. The three principal gold amalgams are: AuHg₂, Au₂Hg, and Au₃Hg.

Hg is Cheap



Hg is Cheap

- From 2004 to 2005, mercury price increased from US\$ 350/flask (\$ 4.6/kg) to US\$900/flask (76lb) (US\$ 12/kg)
- Probably because of pressures on European Union to stop trading
- Actually this was accorded on June 24, 2005 and the EU trading will stop by 2011
- In 2005, ASM are paying more for Hg (~ US\$ 100/kg in Manica, Mozambique)
- Miners now are interested in recycling Hg

Hg is NOT Cheap in Mozambique

- Hg price at Munhena site, Manica = US\$ 100/kg (2005)
- Commercialized in 22g at 50,000 metcals (US\$ 2.2)



Miners Trapped by Gold/Mercury Dealers (Mozambique)

- Gold dealers provide Hg for free but miners have to sell Au for them for low price (Moz 180,000/g = US\$ 7.5/g)
- If miners want to buy Hg from them, the price is US\$ 100/kg

Hg is Very Accessible to Miners

- In most countries, Hg is not allowed to be used in mining
- Hg enters legally the developing countries usually for DENTAL USE
- In many mining sites is sold for DENTAL USE



Probably this large amount of Hg is for "animal dental treatment" (just kidding!!!)

Where This Mercury is Coming from?

Indonesia 1999

- 96 tonnes Hg from Spain
- 33 tonnes from China

Indonesia 2000

- 28 tonnes Hg from Spain
- 17 tonnes from Netherlands
- 3 tonnes from Australia
- 3 tonnes from Japan



Indonesia, 2003

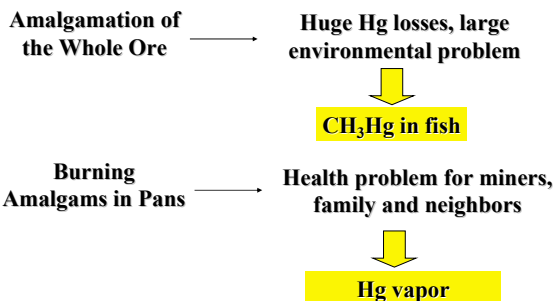
Where This Mercury is Coming from?

- One dealer importing 20 tonnes/a of Hg from the Netherlands for selling to ASM in Zimbabwe and in Mozambique
- In 2000, the Netherlands shipped 245 tonnes Hg to at least 18 countries, most in Latin American/Caribbean region
- Spain shipped 774 tonnes
- UK 200 tonnes
- Germany 105 tonnes
- US (2004) 300 tonnes
- Since 1990, Canada exported 218 tonnes of Hg to US

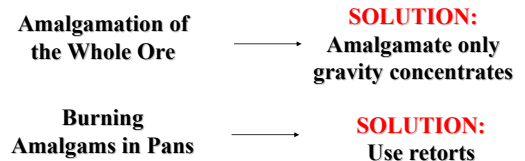
Most of this Hg is of low quality...not useful for electronics but good for ASM

Veiga, Maxson, Hylander, 2004

Amalgamation Process Defines Hg losses (and pathway for humans)



Amalgamation Process Defines Hg losses (Solutions)



Solutions are welcomed by miners if:

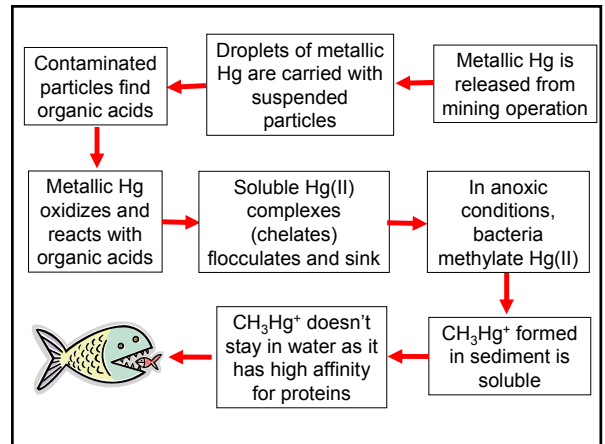
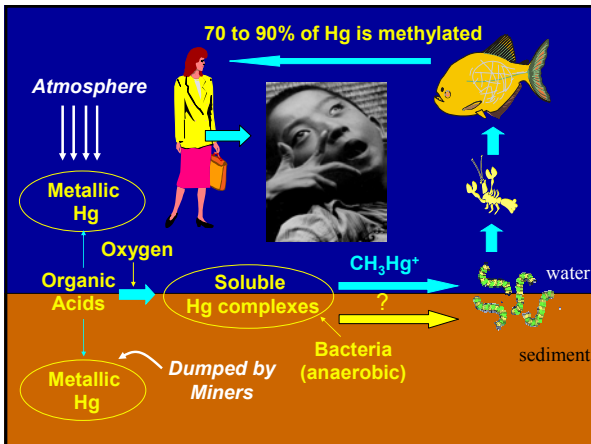
1. Miners see any economic advantage
2. Solutions are LOCALLY available

Amalgamation of the Whole Ore

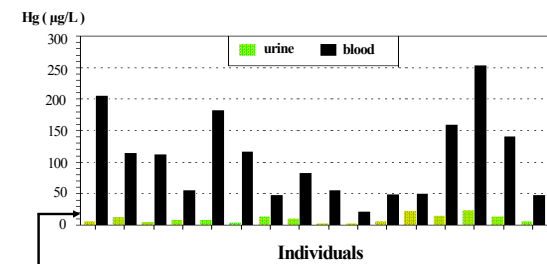
- When the whole ore is amalgamated, fine droplets of Hg are released with tailings (waste)
- This occurs because Hg becomes “pulverized” and loses its coalescence (it does not agglomerate)
- The loss of metallic mercury occurs by attrition of the ore particles with mercury
- Metallic mercury released into the water streams can be transported to long distances associated with suspended particles

Amalgamation of the Whole Ore

- Metallic Hg can be transformed into methylmercury (CH_3Hg^+) which is one of the most toxic substances known
- Methylmercury accumulates very rapidly into the aquatic biota and is biomagnified (goes up into the food web)
- Reaction of metallic Hg with organic acids in oxidized environment is the first step to oxidize mercury and form soluble complexes
- Methylation usually occurs in anaerobic environment



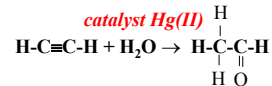
Fish-eating People Are at Risk



Source: GEDEBAM, 1992
People from Tapajós River, Brazil

Methylmercury Poisoning

- First identified in the 50s at Minamata Bay, Japan



- CH_3Hg^+ was generated in the reaction and effluents discharged into the ocean
- Aug. 1997: 10,353 certified victims of Minamata Disease (of which 1246 have passed away)

Congenital Minamata Disease...known in 1972



Photo: W. Eugene Smith (1975)

Typical Minamata Disease Symptoms were not characterized yet in ASM regions but...

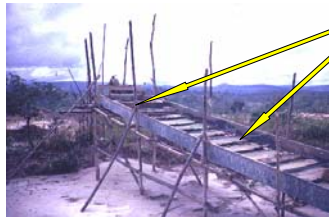


...neurological problems have been already identified in rural communities exposed to Hg vapor or in those that have fish as the main source of protein.

Amalgamation of the Whole Ore

Monitors disaggregate the colluvial ore and pump it to sluice boxes

Sometimes Hg is introduced into the pool



Quite often miners spread Hg in the sluice box

Ore is concentrated in "sophisticated" pieces of equipment

Hg is lost to the environment by attrition



Hg goes with tailings

Amalgamation of the Whole Ore

(it was a common practice in North America during gold rush)

- Between 1860-1895: 6,350 tonnes Hg lost to Carson River, Nevada
- 12,000 tonnes Hg lost in California and Nevada
- Archives from British Columbia: 13kg of Hg/day/sluice used by miners at Cariboo, Canada (1856)



This is 20,000 x more Hg than used by Brazilian ASM

Amalgamation of the Whole Ore

- Use of Copper-amalgam Plates: attrition remove Hg from plates



Zimbabwe, 2003



Brazil, 1995

Amalgamation of the Whole Ore

- Tailing from a hammer mill with copper plate....full of mercury droplets



Photo E. Veiga, Brazil, 2006

Amalgamation of the Whole Ore



El Callao, Venezuela, December 2003

Amalgamation of the Whole Ore



El Callao, Venezuela, December 2003

Amalgamation of the Whole Ore



This amalgam has usually 60% Au and 40% Hg

El Callao, Venezuela, December 2003

Amalgamation of the Whole Ore



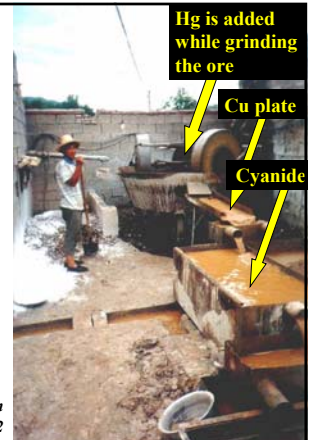
Indonesia, 2002

- In Indonesia: about 110,000 – 350,000 miners (seasonal)
- >100 tonnes Hg released to the environment annually
- Amalgamation of the whole ore followed by cyanidation
- Mercury lost = 100 times the amount of gold produced
- Miners introduce 1 kg of Hg in each ball mill
- Hg is pulverized and 50% of Hg is lost with solids

Amalgamation of the Whole Ore

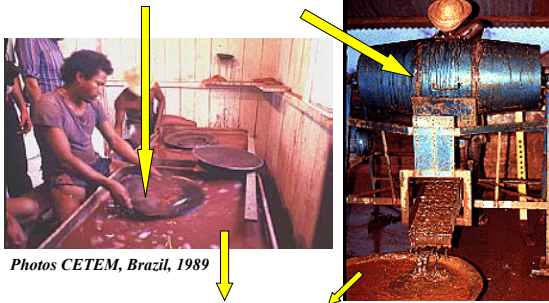
- Amalgamation followed by cyanidation
- Hg becomes more soluble
- Methylation of residual Hg is favoured
- Situation occurring in many countries
- China: 250 tonnes Hg/a released

Photo AJ Gunson
China, 2002



When concentrates are amalgamated, Hg emission is reduced

1 kg of Hg / 60 to 100 kg of concentrate



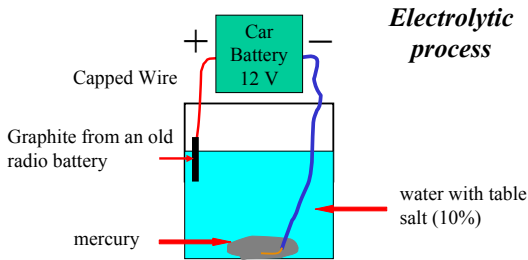
Photos CETEM, Brazil, 1989

Amalgamation tailings (200-500 ppm Hg) cannot be dumped into water streams

Using Activated Hg to Amalgamate (Dr Freddy Pantoja Method)

- Sodium amalgam is more consistent than metallic Hg as it does not form droplets and less Hg is lost and more gold is trapped
- Sodium amalgam does not last too long in water....must be used within 3 hours after activation
Hipoclorito de sódio é também formado e pode ser usado na limpeza das casas

Activating Hg to Amalgamate (Dr Freddy Pantoja Method)



Activating Hg to Amalgamate (Dr Freddy Pantoja Method)



Creporião, Brazil, 2006

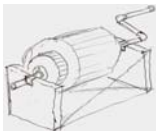
Photos: E. Veiga

Using an Amalgamating Barrel

- One part of Hg to 100 parts of concentrate



Plastic Amalgamation Barrel (20 L)



Plastic Amalgamation Barrel (3 L)

Devised by Edmundo Veiga

Using an Amalgamating Barrel

- A chain or some rubber balls inside the amalgamation barrel help the mixture of Hg with the concentrate
- 30-40 min.
- Activated Hgless losses



After Amalgamation, the Amalgam Must Be Separated from the Heavy Minerals



Brazil, 1993

**WORST SITUATION:
Panning in the water
course**

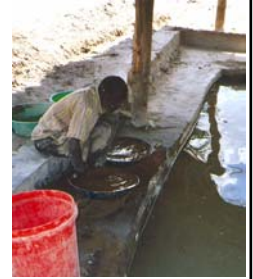
**This forms
hotspots**

After Amalgamation, the Amalgam Must Be Separated from the Heavy Minerals

- Use an excavated tank or a water box



Brazil, 1989



Tanzania, 2004

After Amalgamation, the Amalgam Must Be Separated from the Heavy Minerals

- Excavated pool lined with a plastic trap
- When the pool is full, cover it
- CONTAMINATED TAILINGS MUST NOT BE RECYCLED

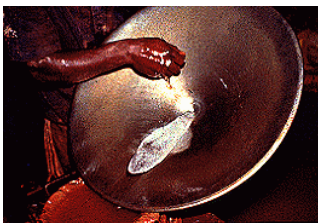


Brazil, 2006

**Filtering Amalgam
(removing excess Hg)**

- The wetting of gold by Hg is not alloying, but a phenomenon of moderately deep sorption, involving some interpenetration of the two elements (Pryor, 1965).
- Amalgam is a solid component and can be separated from the not combined Hg (excess Hg) by filtration
- An ancient filtering process (and widely used by artisanal miners) is to twist and squeeze the amalgam in a scrap of fabric (bare hands)
- Small portion of Hg can be absorbed by the skin

**Filtering Amalgam
(removing excess Hg)**



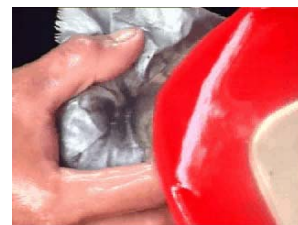
Amalgam is transferred to a piece of fabric

Photos: CETEM



Excess Hg is squeezed off

**Filtering Amalgam
(removing excess Hg)**



The amount of Hg in the amalgam depends how strong the miners squeeze the cloth (filtering process)

Indonesia, 2003

Filtering Amalgam

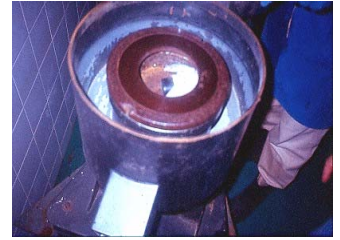
(removing excess Hg)



Manual Squeezing: 60% Au, 40% Hg

China, 2002, Photo: AJ Gunson

Filtering Amalgam



Venezuela, 1995

Using a centrifuge to filter amalgam:

80% Au, 20% Hg

(less Hg remains in the amalgam)

Filtering Amalgam



A centrifuge to filter amalgam can be made with PVC tubes

Devised by Edmundo Veiga

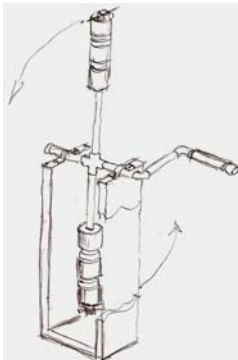
Filtering Amalgam



A centrifuge can be made with PVC tubes attached to a bicycle wheel

Filtering Amalgam

If you don't have a bicycle....



Devised by Edmundo Veiga

Decomposing Amalgam

(separating Hg from Au)

- The decomposition of the amalgam can occur by **leaching amalgam with HNO_3** (Hg is soluble and Au is not) or by **heating** at temperature above 460°C (Hg is evaporated)

Leaching with Acid (HNO_3)

- After filtering, Hg in solution can be recovered by precipitation with aluminum (or iron or zinc or copper) wires immersed into solution
- In countries (e.g. Guyana and Colombia) where miners use acid to leach Hg from amalgam, they do not recover Hg: dispose the toxic solution into rivers

Decomposing Amalgam

(Leaching with Acid)

- Part of the silver can be solubilized by HNO_3
- The method is efficient but very dangerous: mercury oxidation is the first step for methylation.
- Mercury goes into solution as mercury pernitrate - $\text{Hg}(\text{NO}_2)_2 \cdot \text{H}_2\text{O}$
- Human beings have a tolerance of only 0.05 mg/m^3 of this compound in air
- When mercury pernitrate contacts alcohol, fulminate ($\text{Hg}(\text{CNO})_2$) can be produced
- This explodes readily when dry and is used in blasting caps and detonators

Decomposing Amalgam

(Heating)

- Metallic Hg evaporates at 357°C , gold evaporates at 2966°C
- Most Hg compounds evaporates at temperature above 460°C
- “Amalgam Retorting” (evaporation of Hg followed by condensation) is used for centuries
- Condensed Hg can be re-used
- Unfortunately, as Hg is cheap and miners are not aware of the risks of being exposed to Hg vapor, they burn off Hg in open pans...inside and outside their homes

Decomposing Amalgam

(Heating)

When burning amalgams in bonfires or at home, people enjoy watching the color transformation from grey (amalgam) to yellow (gold)



Philippines, 2000

Decomposing Amalgam

(Heating)



Venezuela, 2003

Kids and other expectators stay around inhaling high levels of Hg vapor during amalgam decomposition

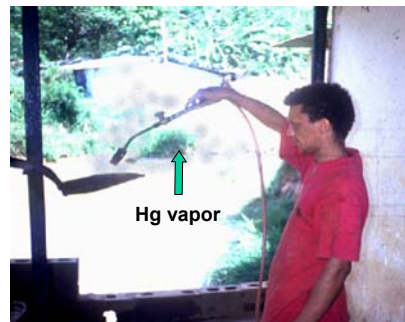
More women are getting directly involved in ASM

As women work carefully, unfortunately more women are in charge of the (dirty) amalgamation work



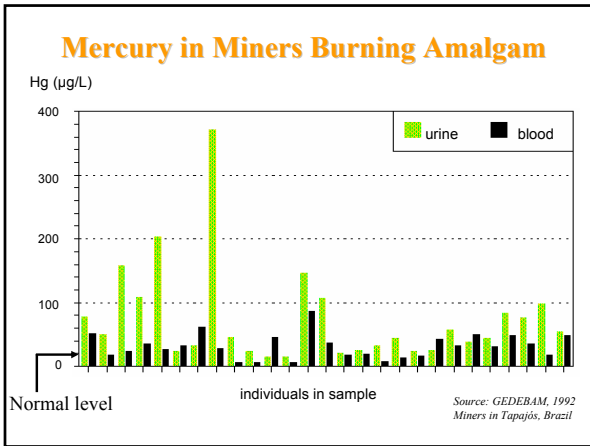
Indonesia, 2003

Amalgam is burned in open pans



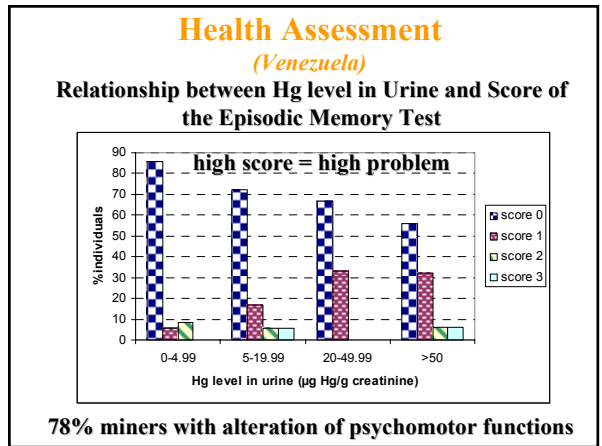
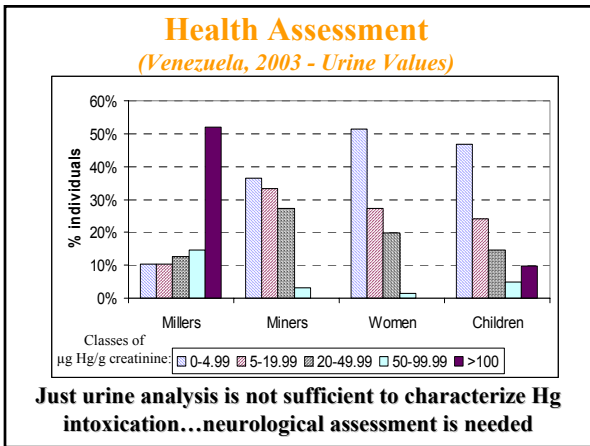
Venezuela, 1995

Hg occupational exposure is... obvious



Typical symptoms of long-term Hg-vapor poisoning (Mad Hatter Disease)

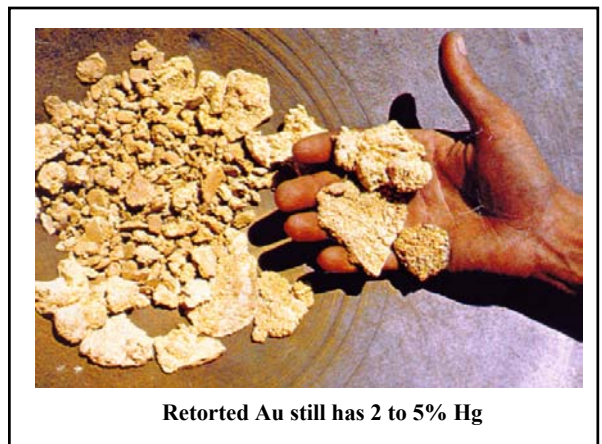
- erethism (exaggerated emotional response)
- psychomotor problems
- loss of memory
- metallic taste
- gingivitis
- blue line at gum margins
- kidney problems
- muscular tremors
- madness
- death



Reproducing Pictures

Original Miner 1 Miner 2 Miner 3

Venezuelan miners (2003) are so intoxicated with Hg that they cannot reproduce easy pictures (and they have high-school education)





Retorted Au (still with Hg) is sold to gold shops and melted: Hg vapor is released in the villages...

Innocent People Breathing Hg Vapor



Brazil, 1993

This individual lived 8 years on top of a gold smelting shop and developed serious neurological problems (from *The Price of Gold*, BBC documentary, 1993)

Burning Amalgam

Any solution is better than this



Venezuela, 1995

Miners usually see the surface of the amalgam becoming yellow and they stop the burning process...the resulting doré can have as much as 20% of Hg inside

Hg in Air

- Normal levels of Hg in air is around 0.001 and 0.01 $\mu\text{g}/\text{m}^3$
- Guidelines:
 - Limit for public exposure: 1 $\mu\text{g}/\text{m}^3$
 - US NIOSH TWA-limit for 10-h workday and 40-h workweek: 50 $\mu\text{g}/\text{m}^3$
 - WHO adopted TWA (time-weighted average) of 25 $\mu\text{g}/\text{m}^3$
- In the artisanal mines of Manica, Mozambique Hg level in air is between 0.3 and 1 $\mu\text{g}/\text{m}^3$
- In mining areas when amalgam is burned in open air ~50,000 $\mu\text{g}/\text{m}^3$

Hg in the Exhaled Air

- Normal levels of Hg in the exhaled air depends on the number of Hg-dental fillings in the mouth
- Normal levels is usually between 0.03 and 0.3 $\mu\text{g}/\text{m}^3$
- In Manica, Mozambique levels in miners are between 1 and 60 $\mu\text{g}/\text{m}^3$ (average of 25 miners = 4 $\mu\text{g}/\text{m}^3$)

Hg in the Exhaled Air



Mozambique, 2005

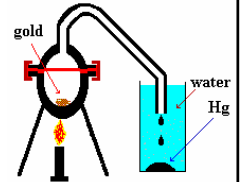
Hg in the Exhaled Air



Mozambique, 2005

Retorts

- Amalgam is heated in a closed system
- Evaporated Hg is condensed and recycled
- Many types: galvanized steel, cast iron, stainless steel
- Cooling system: air or water
- Many prices: from US\$ 3 to 500

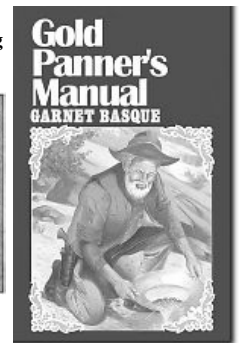
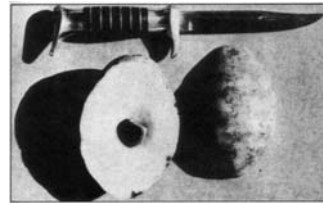


Arguments Used by Miners for Not Using Retorts

Arguments	Reasons	Possible solution
it takes time (sometimes miners become vulnerable to bandits attack when retorting)	low temperature	use air blower in bonfires or blowtorch; avoid crucible made of refractory material such as clay
it needs practice to operate	heating process must be uniform when using blowtorch	training
gold is lost during retorting	iron retorts: amalgam is not visible; bad perceived by miners	glass retorts can demonstrate that gold will not evaporate together with Hg or be trapped
gold sticks in the retort crucible	sometimes gold adheres to crucible bottom	<ul style="list-style-type: none"> • crucible must be filled with soot, or baby powder or clay • avoid overheating
Hg loses coalescence	sometimes condensed Hg disintegrates in fine droplets	NaCl and radio battery to re-activate Hg
gold becomes brown	unknown; probably due to a superficial reaction with iron	<ul style="list-style-type: none"> • still not well studied; • oxidizing atmosphere or use of stainless steel or glazed crucibles; • melt or hammer gold <i>doré</i>

Potato Retort

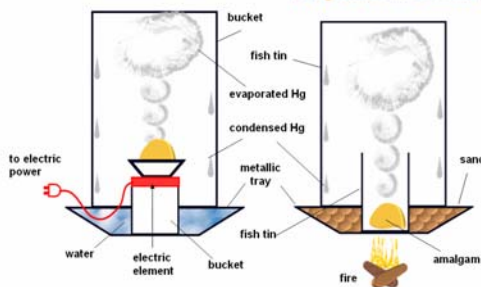
A Canadian booklet suggests retorting amalgam in a scooped potato



Useful but...is this sustainable?

Bucket Retort (China)

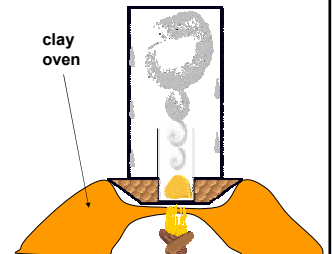
Fish-tin Retort (Papua New Guinea)

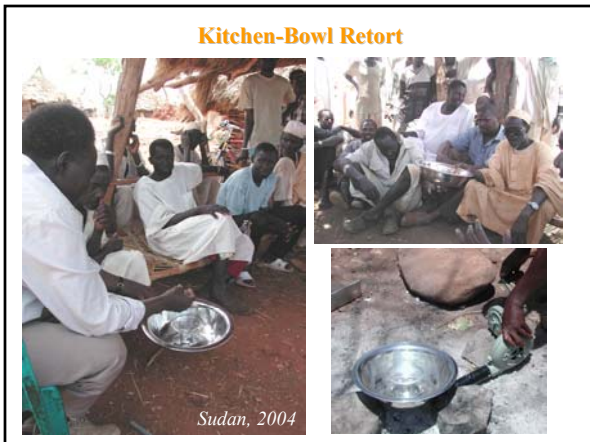
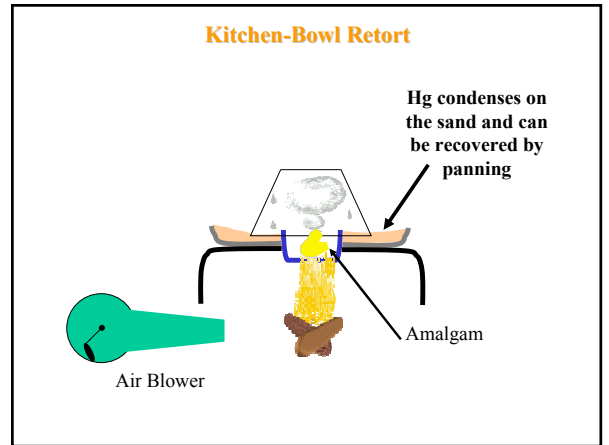
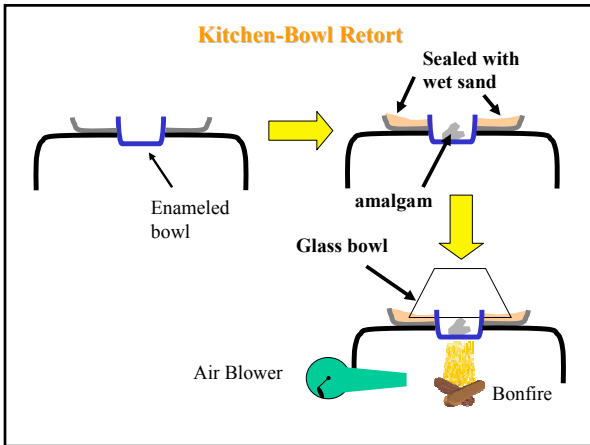
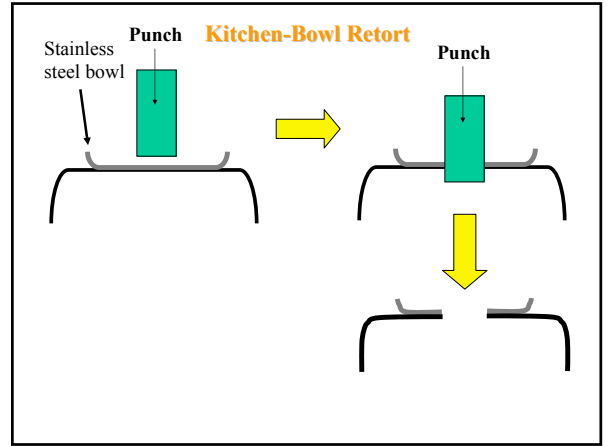
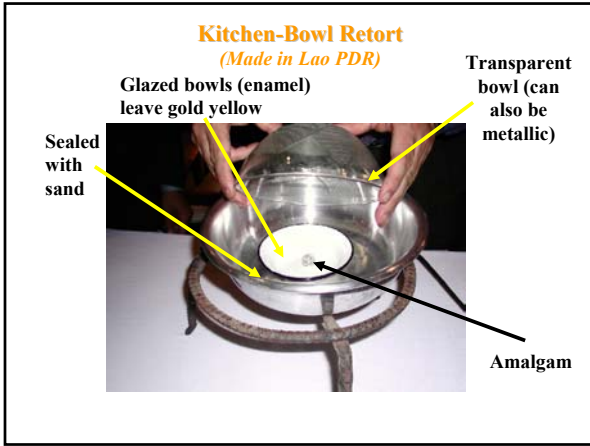


Veiga and Hinton (2002)

Fish-tin Retort (as used in PNG)

Using clay oven as used in West Africa for cooking





Kitchen-Bowl Retort
(Made in Ecuador)



Ecuador, 2004

Kitchen-Bowl Retort



Lao PDR, 2005



Kitchen-Bowl Retort
(Measuring Hg escaping in the Lab)



Burning with Bunsen burner:
15 minutes for 5 g of amalgam



LUMEX (10cm from the sand):
Dry Sand, Max = 50 µg/m³
Wet Sand, Max = 5 µg/m³

Kitchen-Bowl Retort
(in the Lab)



Despite the visual control,
the glass cover takes almost
15 minutes (with water being
added) to cool down

Miners may prefer the steel
cover (cools down in 5
minutes)

Using Kitchen Bowl Retorts
Retort in the bonfire and a miners fanning it



Mozambique, 2005

Using Kitchen Bowl Retorts



Stainless steel or enameled steel
makes the retorted gold yellow

The contact of retorted gold
with iron makes the gold
surface brown....low price
paid by the gold dealers



Brazil, 2006



Kitchen-Bowl Retort

The retort can be placed on top of a paint tin with charcoal

Brazil, 2006



OCT 24 2006

Crepolizão, Brazil



Brazil, 2006



Brazil, 2006

Using Kitchen Bowl Retorts

- When burning amalgam in open air, miners are exposed to Hg levels around $50,000 \mu\text{g}/\text{m}^3$
- In Mozambique, using the kitchen-bowl retorts, Hg in air at nose level decreased to $0.4 \mu\text{g}/\text{m}^3$
- 1 meter from the bowl = $3 \mu\text{g Hg}/\text{m}^3$
- 0.1 m from the bowl = $35 \mu\text{g Hg}/\text{m}^3$
- WHO guideline for worker exposure = $25 \mu\text{g Hg}/\text{m}^3$ (TWA - time weighted average to which workers may be exposed for 8 hours per day without risk)

Using Kitchen Bowl Retorts

Measuring with a LUMEX Hg escaping from the retort



Mozambique, 2005

Using Kitchen Bowl Retorts



Zimbabwe, 2005

Using Kitchen Bowl Retorts

- A stainless steel ashtray can be used for larger amount of amalgam
- Amalgam needs to be smashed (or broken in pieces) before retorting



Mozambique, 2005

Using Kitchen Bowl Retorts

Kerosene stoves increase burning temperature
(and reduce retorting time)



Mozambique, 2005

Using Kitchen Bowl Retorts

Cover does not need to
of glass

Metal cover actually
cools down faster than
glass covers

Wet sand must be
introduced here to seal
the retort

Mozambique, 2005



Using Kitchen Bowl Retorts

- In Mozambique:
 - Time of retorting/cooling in a bonfire was 20-30 minutes using glass cover (1 g of gold)
 - Time of retorting/cooling using a kerosene stove and steel cover was 10 minutes (3 g of gold)
- It is important to have the glass cover (transparency) at least at the first tests to demonstrate to miners that gold does not disappear

Using Kitchen Bowl Retorts

Using a torch to burn amalgam



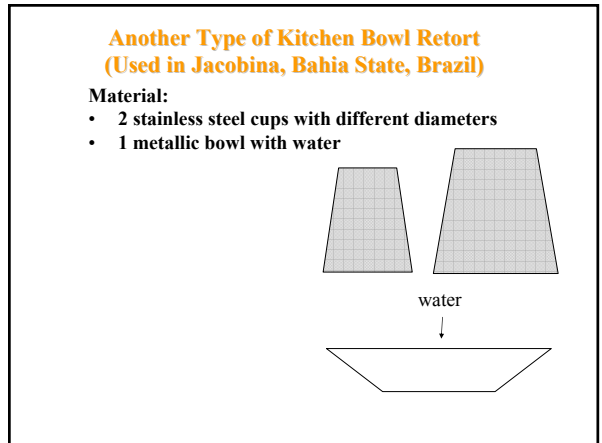
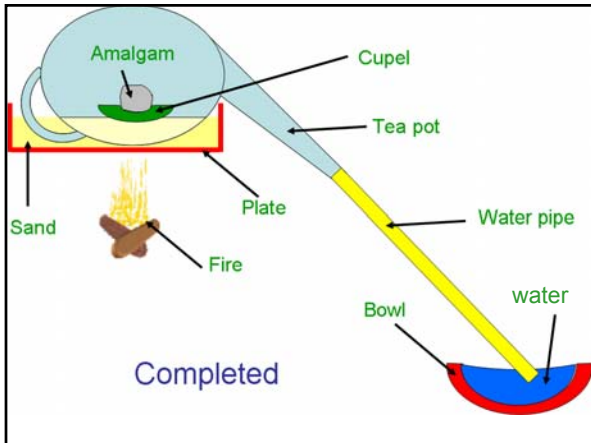
Zimbabwe, 2005

Using Kitchen Bowl Retorts

Separating Hg from sand by panning after retorting

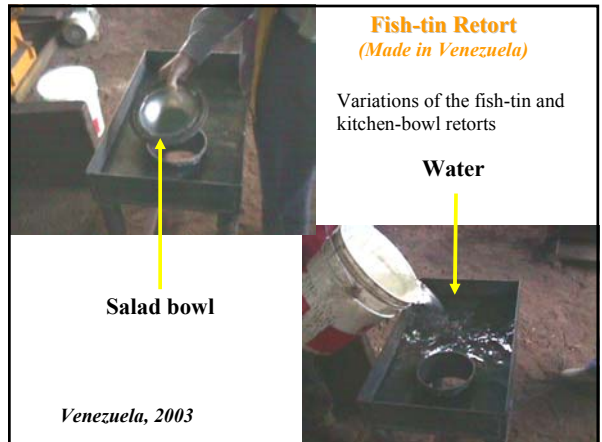
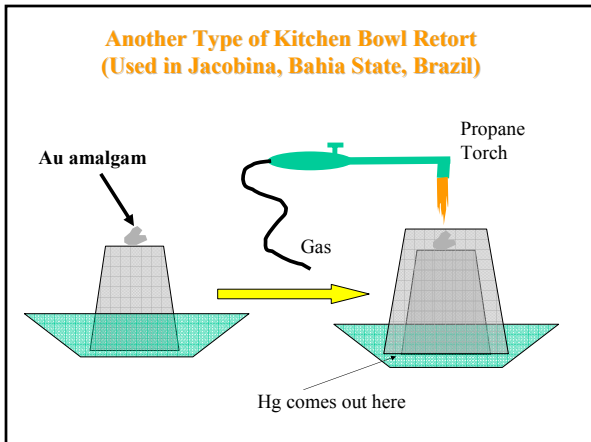


Mozambique, 2005



Material:

- 2 stainless steel cups with different diameters
- 1 metallic bowl with water

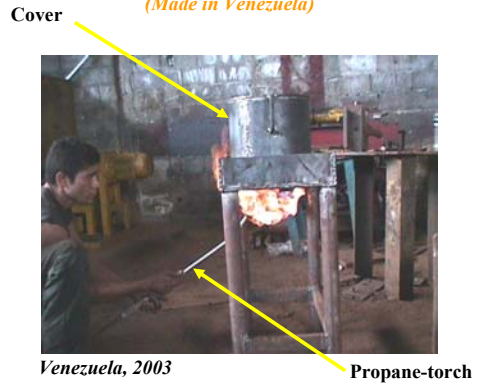


Fish-tin Retort
(Made in Venezuela)



Venezuela, 2003

Fish-tin Retort
(Made in Venezuela)



Venezuela, 2003

Fish-tin Retort
(Made in Venezuela)

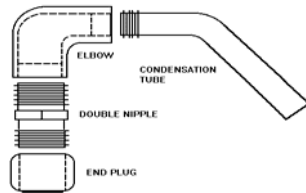


Cover

Water

Amalgam

Home-made retort (RHYP)

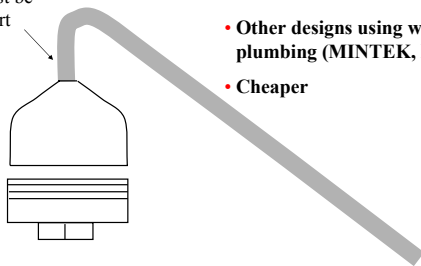


- Devised by prof. Raphael Hypolito, Univ. São Paulo
- Made of water plumbing material (galvanized steel)
- Size: from 3/4 " to 4 "
- Ideal size 1 1/2 " to burn 10 to 20 g of amalgam
- Cost: from US\$ 5 to 10



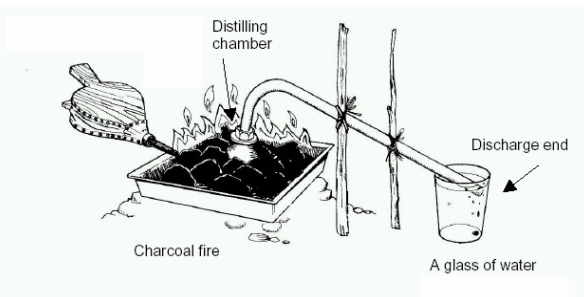
Home-made retort (RHYP)

This part must be short



- Other designs using water plumbing (MINTEK, ITDG)
- Cheaper

Home-made retort (RHYP as Promoted by ITDG)



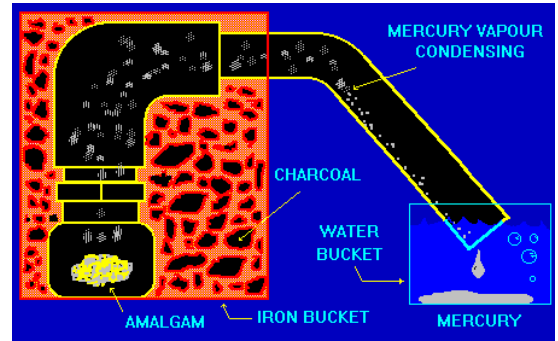
Home-made RHYP retorts (Problems)

- It leaks (Hg escapes) if not well set up
- Zinc from galvanized steel must be burned off from inside and outside (this can be toxic)
- Gold sticks inside the retort (lining with clay is needed)
- Heating in a bone fire takes long time
- Gold comes out brown (smash it to turn it yellow)

"Do not worry if, the first time you use the retort, only a small part of the expected amount of mercury is recovered. Most of the mercury is normally trapped in the retort, and will be recovered in second and subsequent uses." (ITDG)

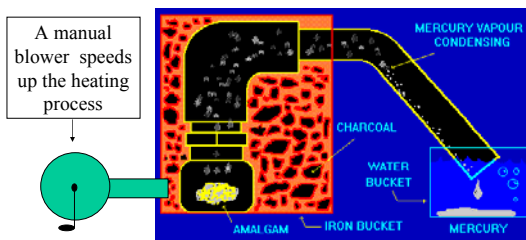
Home-made Retort (RHYP)

- Ideally: heat the entire body in a charcoal bed



Home-made Retort (RHYP)

- Heating time can be shortened



Building RHYP Retorts in Palangkaraya, Indonesia

- Larger sizes can be made: 2" (as in the picture)
- In Indonesia, heating was provided by gasoline torch
- This is faster than charcoal



Indonesia, 2003

Building RHYP Retorts in Palangkaraya, Indonesia

- Home-made torch
- It uses gasoline
- Air pumped by foot



Indonesia, 2003

Building RHYP Retorts in Palangkaraya, Indonesia

US\$ 5/ each



Miner in Guha, Kahayan River using the RHYP retort (burning with gasoline torch)

UNIDO rep., Metal worker and Mining and Energy Provincial Office representative

Indonesia, 2003

Building RHYP Retorts in Kadoma, Zimbabwe



Zimbabwe, 2003

Building RHYP Retorts in Gugub, Sudan



Sudan, 2004

Building RHYP Retorts in Gugub, Sudan



Sudan, 2004

Building RHYP Retorts in El Callao, Venezuela



Venezuela, 2003

Building RHYP Retorts in Munhena, Mozambique



Mozambique, 2005

Building RHYP Retorts in Munhena, Mozambique



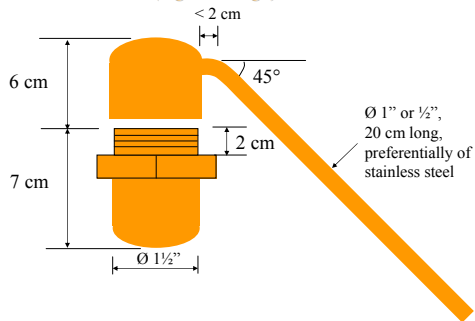
**Levels of Hg
escaping**
0.1 m = 30 $\mu\text{g}/\text{m}^3$
1 m = 2 $\mu\text{g}/\text{m}^3$
Nose = 1.8 $\mu\text{g}/\text{m}^3$



Mozambique, 2005

CETEM Retort

(a good design)



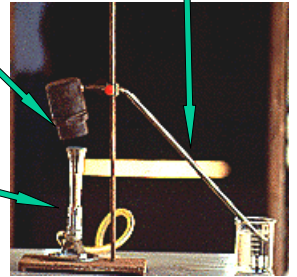
Retort devised by CETEM, Brazil

CETEM Retort

Crucible is well sealed

Air cooled

Operate with cooking gas

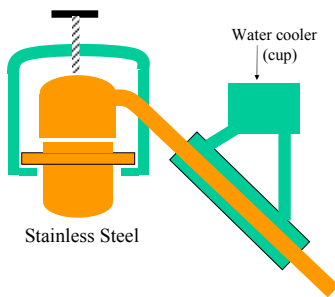


Retort devised by CETEM, Brazil



GTZ retort, Germany

GTZ Retort in Sulawesi, Indonesia



Stainless Steel

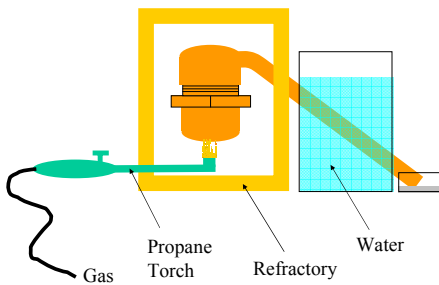
Retorts



Suriname, 1996

Colombian Retort

(Colombian Still)



Pinzón, J.M.; Contreas, R.; Bernardy, C., 2003. A new still for the prevention of mercury poisoning in small-scale gold mining by amalgam extraction. *Geofisica International*, v.42, n.4, p.641-644

Retorts




Good design: crucible of stainless steel and the rest of the body of C-steel

However, the crucible is too thick...it takes more than 30 min to retort

This crucibles are preferred

**Salad bowl:
replaceable and
thin**

Retorts



Venezuela, 2003

Retorts

**Stainless Steel
Cup = US\$ 1**



Venezuela, 2003

Retorts

Very good design

this pipe must be made
of steel (not copper)

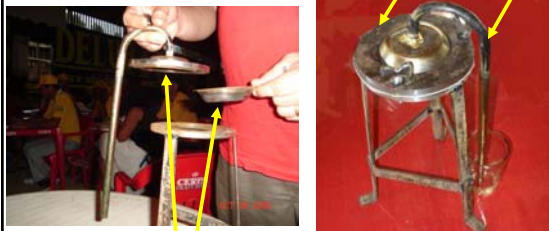


Venezuela, 2003

Retorts

The rest of the
retort is made of
C-steel

Thin stainless steel
dish
(US\$ 1)




Brazil, Creporizão, 2006

Retorts

Always remove this
water glass before
shutting the fire

**IF YOU FORGET:
WATER WILL
ENTER THE HOT
RETORT AND IT
CAN EXPLODE**



Brazil, Creporizão, 2006

**Asbestos
joint**



Creporizão, 2006



Creporião, 2006

Heating Process

Heating time in a bonfire can be shortened with an air-blower



Tanzania, 2004

Heating Process

Air-blower in kitchen-bowl retort



Sudan, 2004

Increasing Bonfire Temperature ("Mvuto" = bellows) using a plastic bag



Zimbabwe, 2006

Using Stainless Steel Cups as Crucible

- Stainless steel cups (or ashtrays) are good because:
 - They are cheap (US\$ 1 – 2) and easy to find them in kitchen stores and supermarkets
 - They are thin (warm up quickly)
 - They are replaceable
 - Gold comes yellow
 - Gold does not stick on the cup (but a little black soot before starting retorting is always advised)
 - Enameled Steel (coffee cups) are also good

How to operate a retort

- New retorts: burn the metallic crucible (inside and outside) and cool it down
- Cover the interior of the crucible: use fine clay or soot (black fume) using a reducing torch and cool it down
- Introduce the amalgam and spread it inside the crucible (some miners wrap it on paper)
- Heat the entire body at low temperature for 5 to 15 min
- See bubbles of air coming out in the water glass at the end of the cooling tube **IMMERSED IN A GLASS OF WATER**
- Increase temperature and distribute heating all over the retort body
- Tap the pipe as Hg can be stuck inside
- Increase temperature and concentrate flame at the crucible bottom
- **REMOVE THE TIP OF THE RETORT FROM WATER** before shutting the fire
- Cool retort in water before opening. Do not open warm retorts

Retorted gold is not yellow options:

- Lining with clay (easy!!!)
- Use stainless or enameled steel as crucible (easy!!!)
- HNO₃ or HCl to clean gold after burning (not easily accessible, and toxic)
- Melt gold (high temperature 1063 °C) (not easy)
- Hammer gold doré after retorting (easy!!!)
- Convince gold buyers (hard as they use this to reduce gold buying price)
- Burn amalgam in an oxidizing environment: in fume hoods or add an oxidizing agent (hard to find)

Building RHYP Retorts in El Callao, Venezuela



Venezuela, 2003

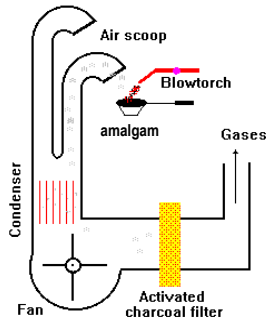
Option to have yellow gold:

burn amalgam in oxidizing environment such as a fume hood (used in Peru, Gama Project)

Hg is condensed and air is filtered with charcoal with iodide solution

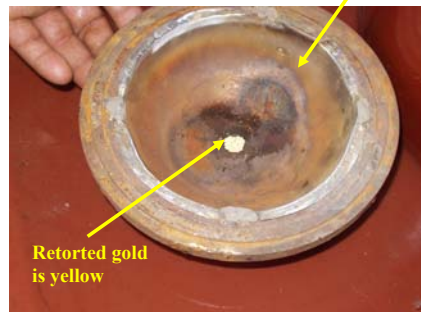
Problems:

- Expensive
- Operation is delicate
- Risk of exposure



Option to have yellow gold:

Stainless steel kitchen bowl



Venezuela, 2003

Miners cannot see retorting process

option: Thermex glass retort

- Quartz crucible, stainless steel condenser and glass recipient
- Good for demonstration not for operation (expensive & fragile)



Photo: UNIDO

Comparing Retorts

	RHYP (water plumbing)	kitchen-bowl	CETEM	Venez. (fish-in)	Colombian Still	GTZ (water cooled)	Thermex
crucible material	Galvanized steel	C-steel	Low C-steel	Stainless steel	Stainless steel	Stainless steel	High silica glass
durability	Low	Low	Medium	Medium	High	High	Low
price (US\$)	5-20	5-20	20-50	10-40	80-90	100-200	400-500
possibility of local fabrication	High	High	Medium	High	Medium	Medium	None
retorting time (min) with blowtorch	15-20	10-15	15-20	10-15	10-20	15-20	20-30

Miners do not have practice to amalgamate and retort gold
 option: Amalgamation Centers (like in Venezuela)

retorts



Trained operators do the job for miners

Retorts

(in Amalgamation Centers)

- Exhaustion system on top remove escaping Hg
- Use of dust masks are not appropriate but it is better than nothing
- Gas washing process: potassium iodide solution



Venezuela, 1995

Use of Masks

- Dust masks are not adequate as they retain just a minor part of the Hg vapors
- Hg condenses on the mask
- Operators should discard the masks after use otherwise they inhale all Hg condensed (and evaporated) from the masks
- Masks with activated charcoal impregnated with potassium iodide are appropriate



Venezuela, 1995

Use of Masks

- Hg mask made of sandwiched charcoal-impregnated cloth
- Making a comfortable, long-lasting mask which will filter out all mercury vapour at concentrations up to 0.1 milligram per cubic meter (that is, twice the time limited value, TLV) for 150 hours.



<http://www.mercurysafety.co.uk/products/vaprmask.htm>

Use of Masks

- 3M Mercury/Chlorine Gas Respirator Cartridge is NIOSH approved against mercury vapor or chlorine
- US\$ 22



<http://www.professionalequipment.com/xq/ASP/ProductI D.2654/id.131/subid.432/qx/default.htm>

Conclusion

- It is not easy to convince miners to adopt retorts
- They do not believe in Hg vapor intoxication
- Impotence can be used to convince them
- Easy operating and accessible (locally made) retorts must be brought to their attention
- Training is needed as well as technical assistance
- Glass retorts: excellent for demonstration not for operation
- Home-made retorts with plumbing or kitchen bowls: sustainable (miners can make)