



NERD

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Alternatives to Eliminate the Use of Mercury in Artisanal Gold Mining

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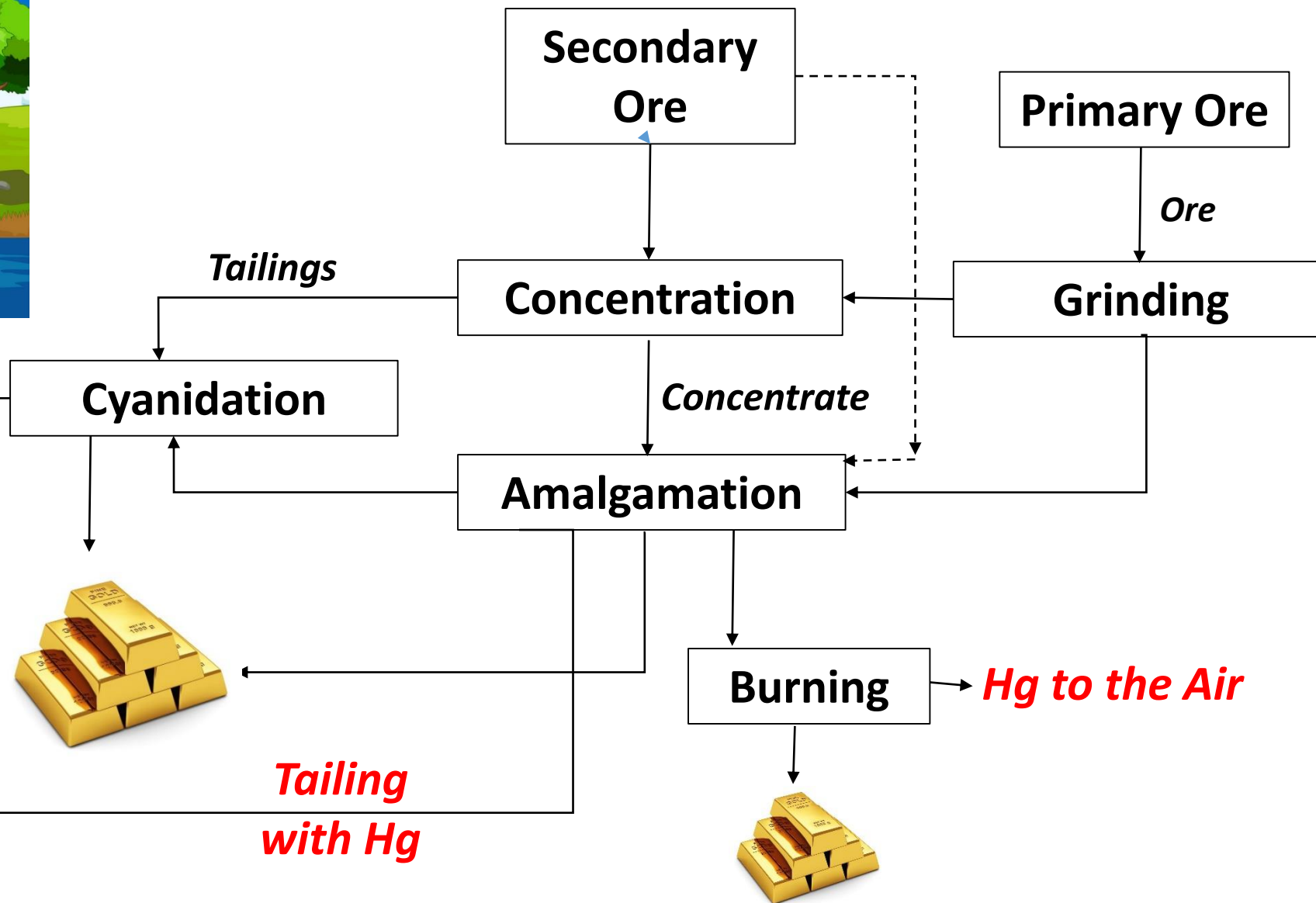
How Artisanal Gold Miners Use Mercury



Tailings with $\text{Hg}(\text{CN})_2$



Tailing with Hg



After 40 Years of Attempts to Eliminate Mercury from AGM

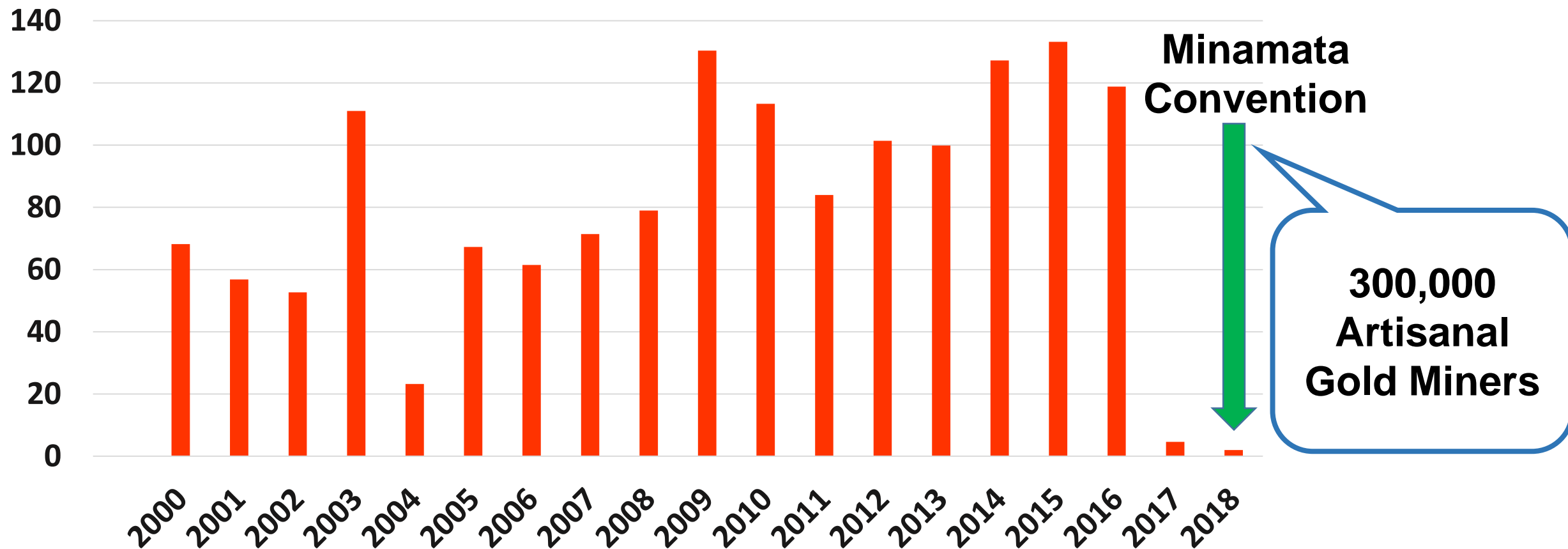
- **Which approaches have been tried?**
 - 1. Legal Approach (formalization, enforcement, Minamata Convention, etc.)**
 - 2. Environmental-health Approach (e.g. showing the miners and scientists that Hg is polluting)**
 - 3. Technological Approach**

The Legal Approach Has Been Centered on the UN Minamata Convention

- **The UNEP Minamata Convention controlling exports and imports of mercury entered into force on Aug. 16, 2017**
- **Until Sept 2021 (128 countries signed and 127 ratified the Convention)**
- **Main result:** Official export-imports of Hg are not correctly provided by the countries
- **Hg Price increased substantially Hg smugglers loved it**

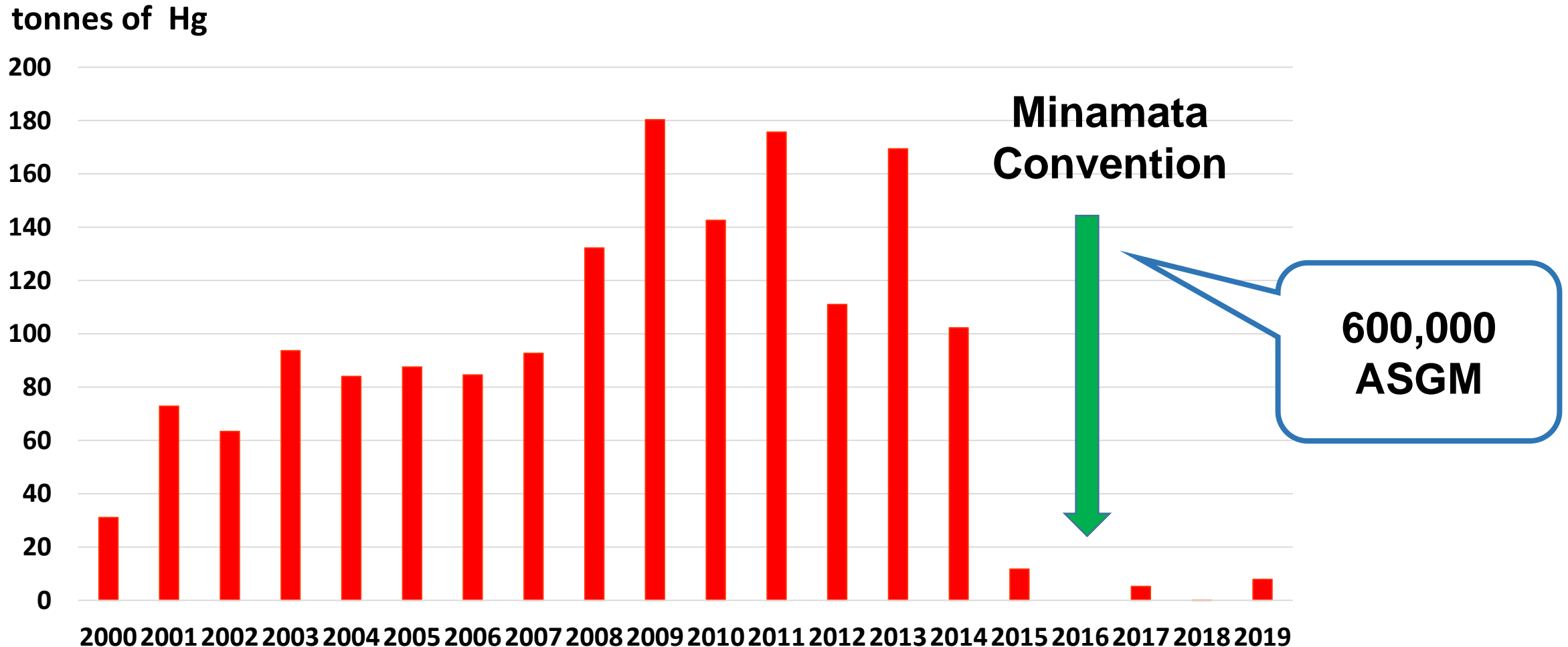
Tonnes of Hg Imported by Colombia

tonnes of Hg



Source: UN COMTRADE, 2020

Tonnes of Hg Imported by Peru



Source: UN COMTRADE, 2020

The Environmental-Health Has Been Tried but...

- **Miners do not believe in scientists and do not read scientific papers or technical reports**
- **There is no long-term engagement of scientists with miners**
- **Press tends to create “scandals” based on scientific findings**
- **Main Results:** distance between science and miners
- **Lots of pseudo-scientists are now talking loud**

By Richard C. Paddock

Nov. 9, 2019

CIDAHU, Indonesia — Thousands of children with crippling birth defects. Half a million people poisoned.

BBC NEWS | MUNDO

Noticias América Latina Internacional

Cómo el mercurio mata lentamente a los mineros

(how mercury kills miners slowly)

The New York Times

The Hidden Cost of Gold: Birth Defects and Brain Damage

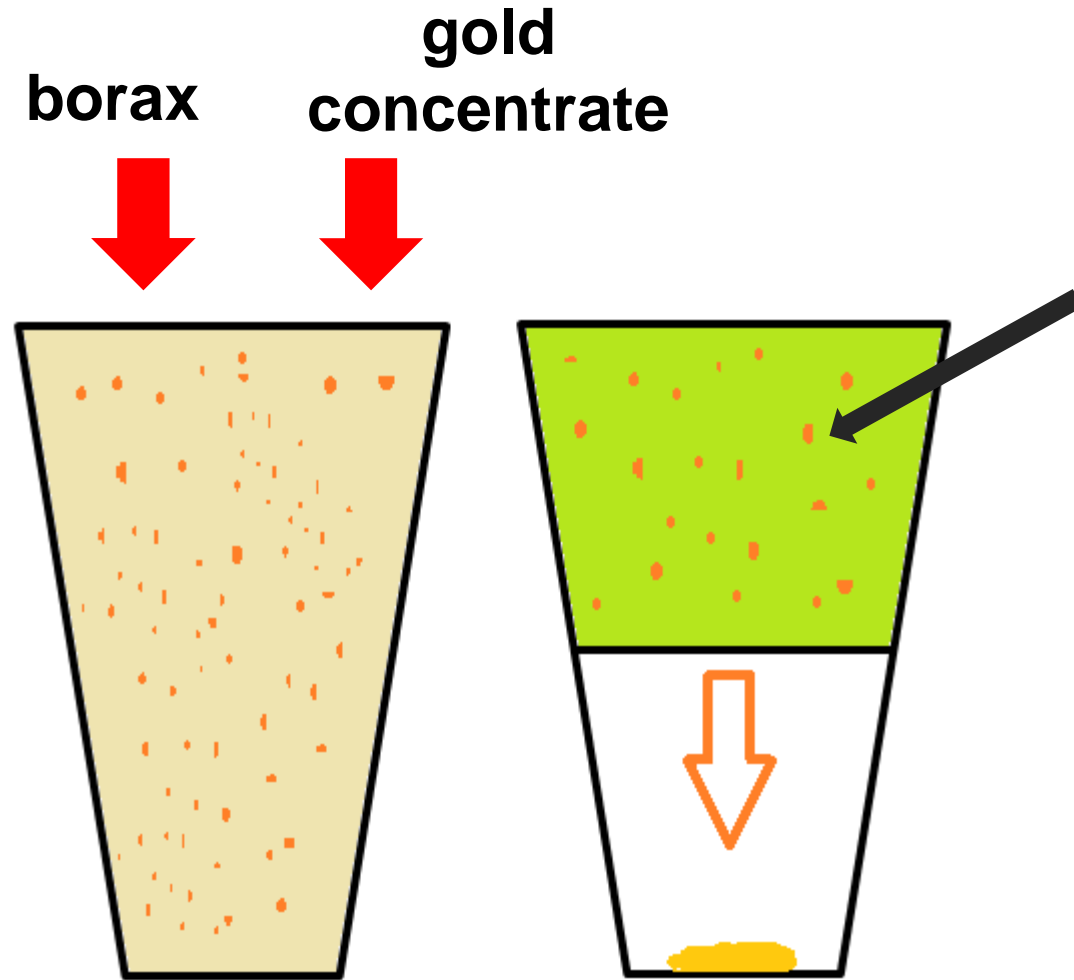


An outlaw gold miner on the Indonesian island of Sumbawa examining a nugget of gold combined with toxic mercury, which is used to extract the precious metal from crushed ore. Adam Dean for The New York Times

The Technological Approach Has Also Been Tried but...

- Changes in technology need **SKILLS** and **MONEY**
- Too much focus of Gravity Concentration and direct smelting...this definitely can eliminate amalgamation of some ores (alluvial) but is this the main problem?
- Amalgamation of the whole ore is the main problem
- Adequate concentration (gravity + flotation) and extraction of gold from concentrates require \$

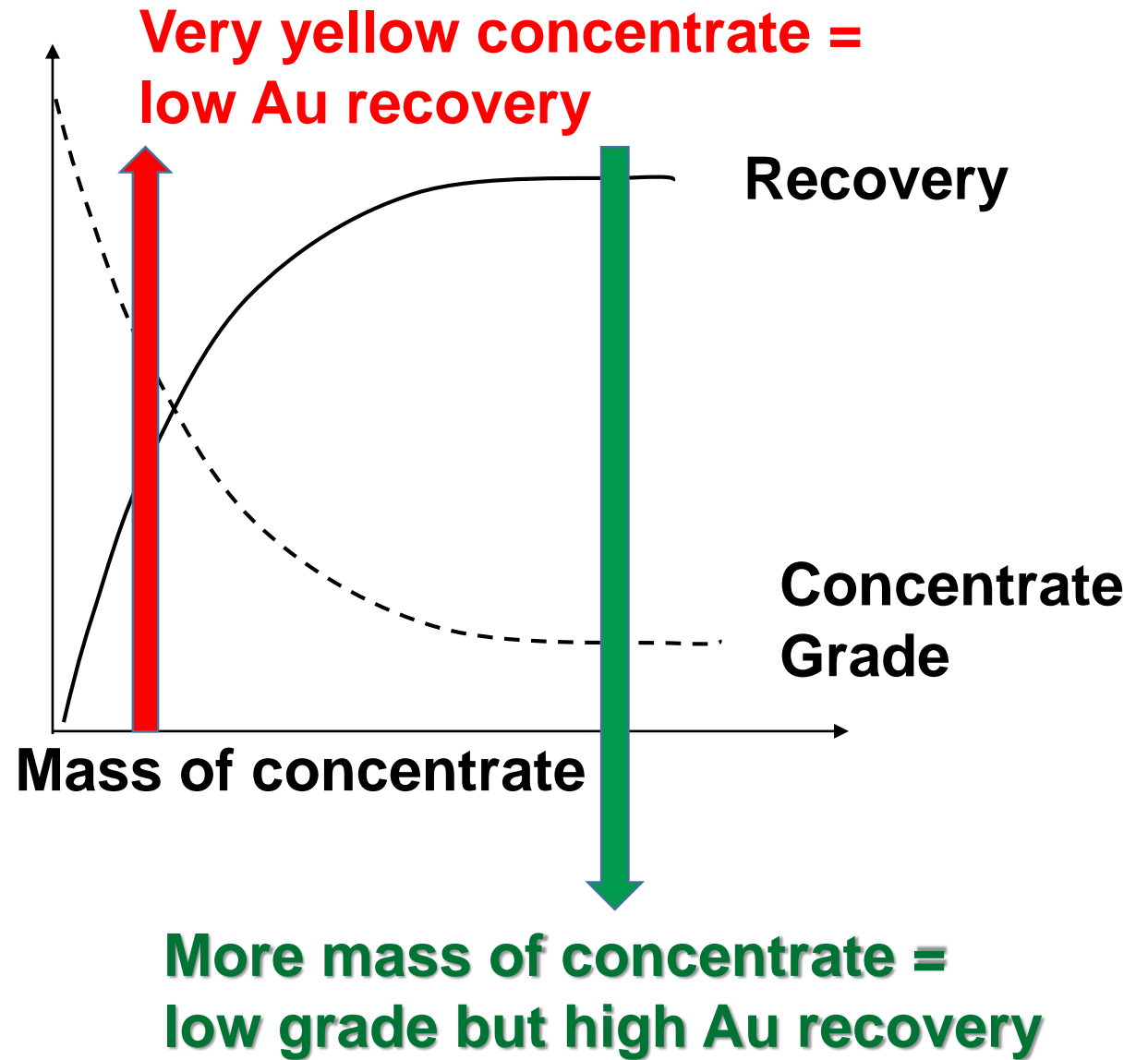
Direct Smelting of Concentrates



Gravity Concentration is Not a Panacea

Borax Method?

How to convince a
miner to lose 90% of
their gold in a
gravity concentrate
to be able to melt it?



Who Are the Main Hg Polluters? (out of 20 million AGMs)



	Micro miners	Proc. Centers
ASGM in the world	90%	10%
Gold Production	20%	80%
Hg Releases	10%	90%
Attention of the Interventions	90%	10%

Equipment for Micro-miners (<2 tpd of ore) CICAN Project (Colombia)



- Use an iron chain for grinding from 100-200 kg/h to -1 mm
- 1 HP engine
- Cost in Colombia = US \$ 400-500



Equipment for Micro-miners (<2 tpd of ore)

CICAN Project



Proyecto CO-01

Realización de equipamientos a bajo costo para los pequeños mineros artesanales de Colombia, particularmente para los jóvenes de las regiones metas.



Shaking Table: 200 kg/h, 1 HP, US\$ 100 – 200.

Flotation: Fiber glass, 71 Liters, 20 kg of ore/batch, 0.5 HP, US\$ 300

How about the Processing Centers?

- They must **CHANGE** or **BE ELIMINATED**
- How?
- Transforming these Centers into real processing companies to **co-exist** with AGM
- They should **BUY** the ores from miners and stop exploiting them using amalgamation to extract the easy free Au and retaining rich tailings to be leached with CN
- Pay **FAIR** price for the gold in the ores

How about the Processing Centers?

- Owners of Processing Centers know that Hg is not useful to amalgamate unliberated gold (like in hard rocks)...the worse for miners, the better for the P.C.
- How to change?
- They **MUST PAY** the miners more than 50% of the gold content in the ore, depending on the grade
- What do they do with the ore they buy?
- Concentrate and leach with cyanide or other lixiviants

Gold Doesn't Need to Be Liberated to Be Concentrated

- Gold **must** be **LIBERATED** to be amalgamated



- Gold **must** be **EXPOSED** to be leached with cyanide

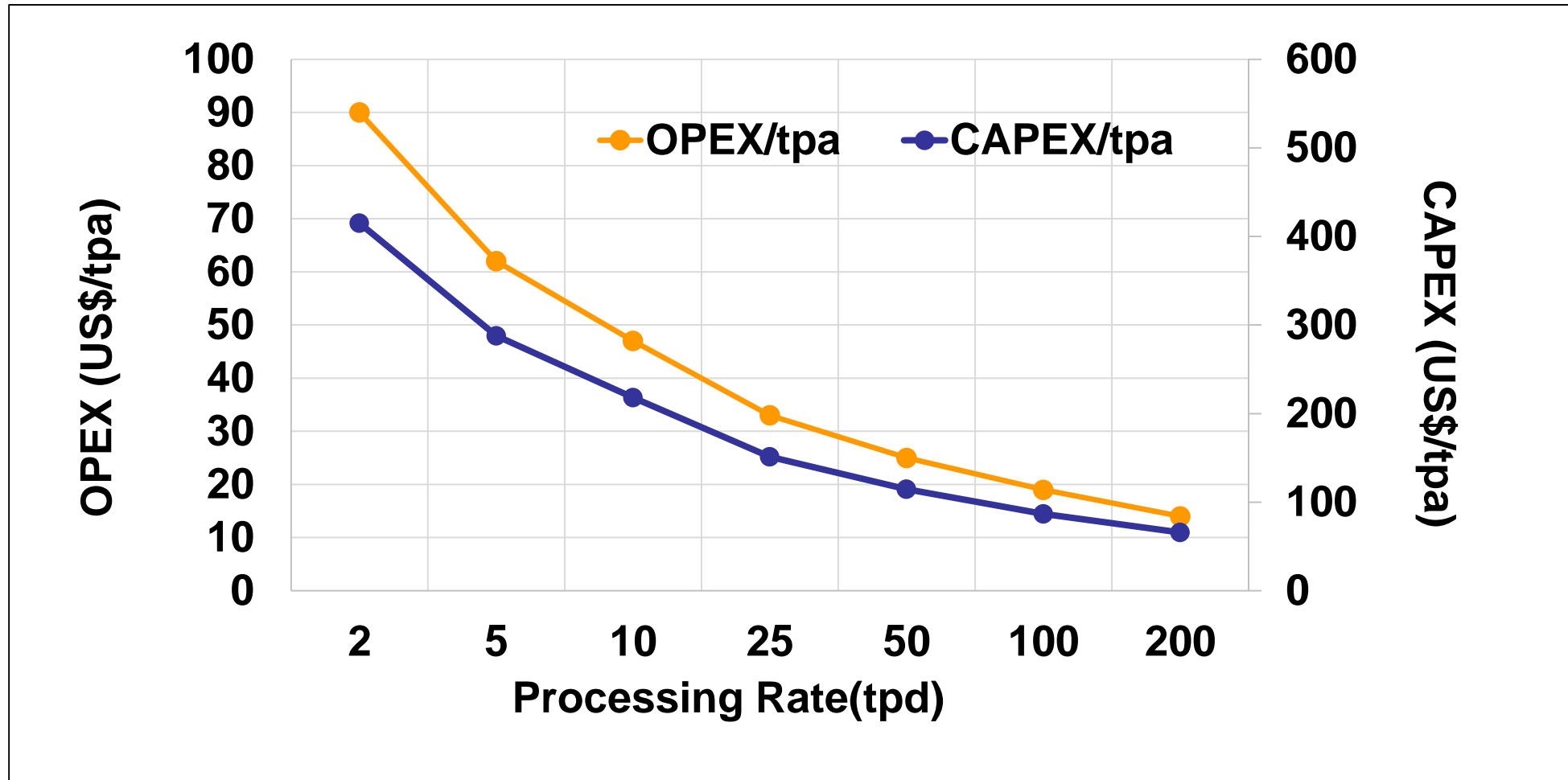
Cost of a Processing Plant

tonnes processed per day (tpd)	CAPEX, US\$	OPEX, US\$/a	CAPEX (US\$/tpa)	OPEX (US\$/tpa)
200	3,946,266	855,091	66	14
100	2,603,565	564,150	87	19
50	1,717,712	372,200	115	25
25	1,133,267	245,560	151	33
10	653,986	141,708	218	47
5	431,470	93,492	288	62
2	248,993	53,953	415	90

Note: 300 days/a of operation, tpa = tonnes processed per annum

CAPEX 50 tpd = \$ 34000 per tonnes processed per day
CAPEX 10 tpd = \$ 65400 per tonnes processed per day

Cost of a Processing Plant



Advantages of Co-existence

- **Processing companies provide assistance to artisanal miners in the mines and process the ores sold by them**
- **No investment or operating costs for miners**
- **Miners receive more \$ (more for the Au content)**
- **No mercury or cyanide in the hands of miners**
- **Miners do not need to obtain environmental permits (use subcontracts)**

Advantages of Co-existence

- Many examples in Colombia, Peru, Nicaragua and now in Costa Rica
- Miners mine and Companies process
- Different types of co-existence:
 1. Buy ore and process in a plant
 2. Share results of the processing with miners
- **Disadvantage:** long process of create trust

Newlox Model

- **Operating in Costa Rica since 2014 buying Hg-contaminated tailings (85 tonnes/day)**
- **Remove Hg, concentrate and leach concentrates with cyanide**
- **Now starting a 150 tonnes/day plant in partnership with the artisanal mining cooperative**
- **After paying the operating costs, the profit is shared 50-50%**

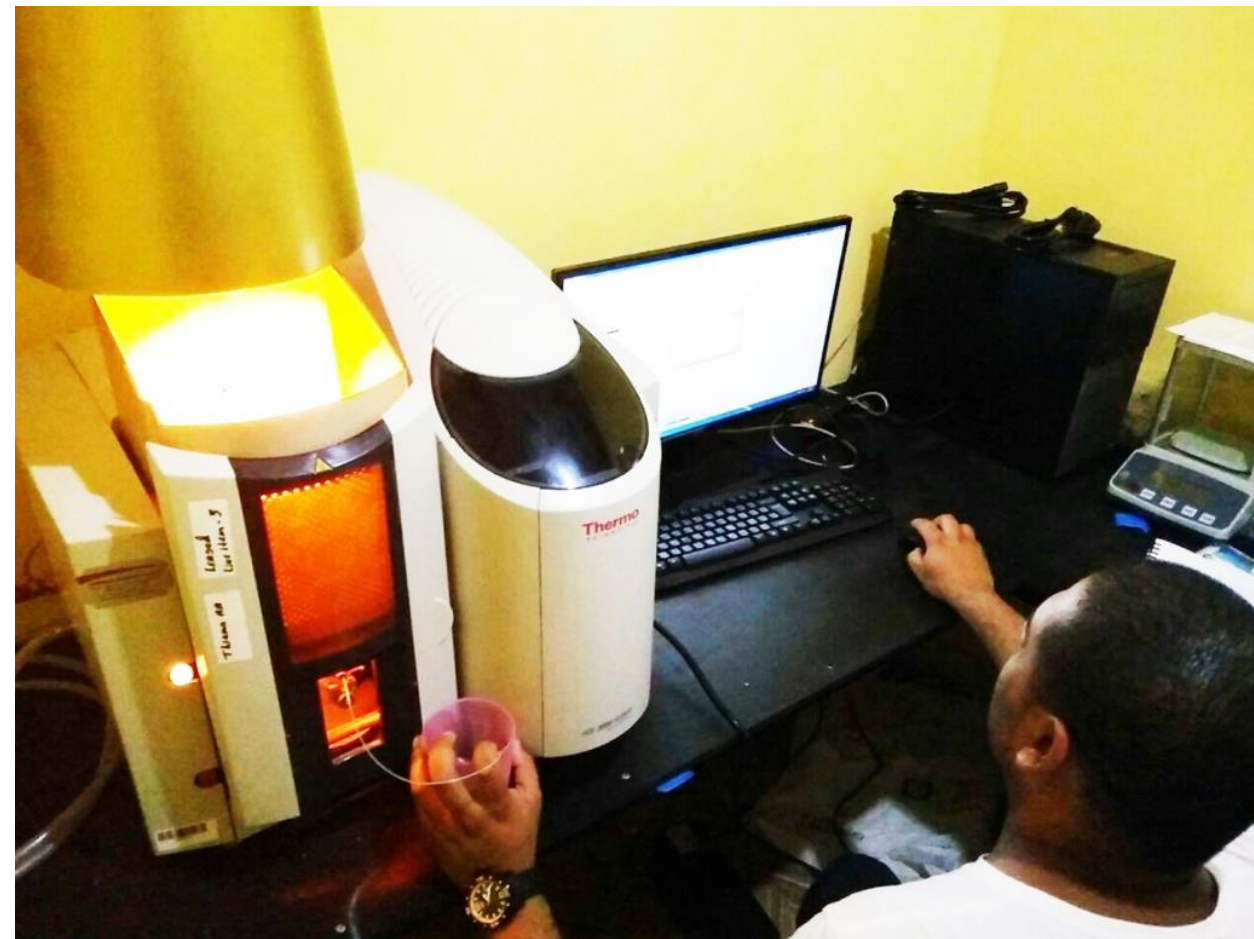


Plant for Re-processing ASGM Tailings



Costa Rica

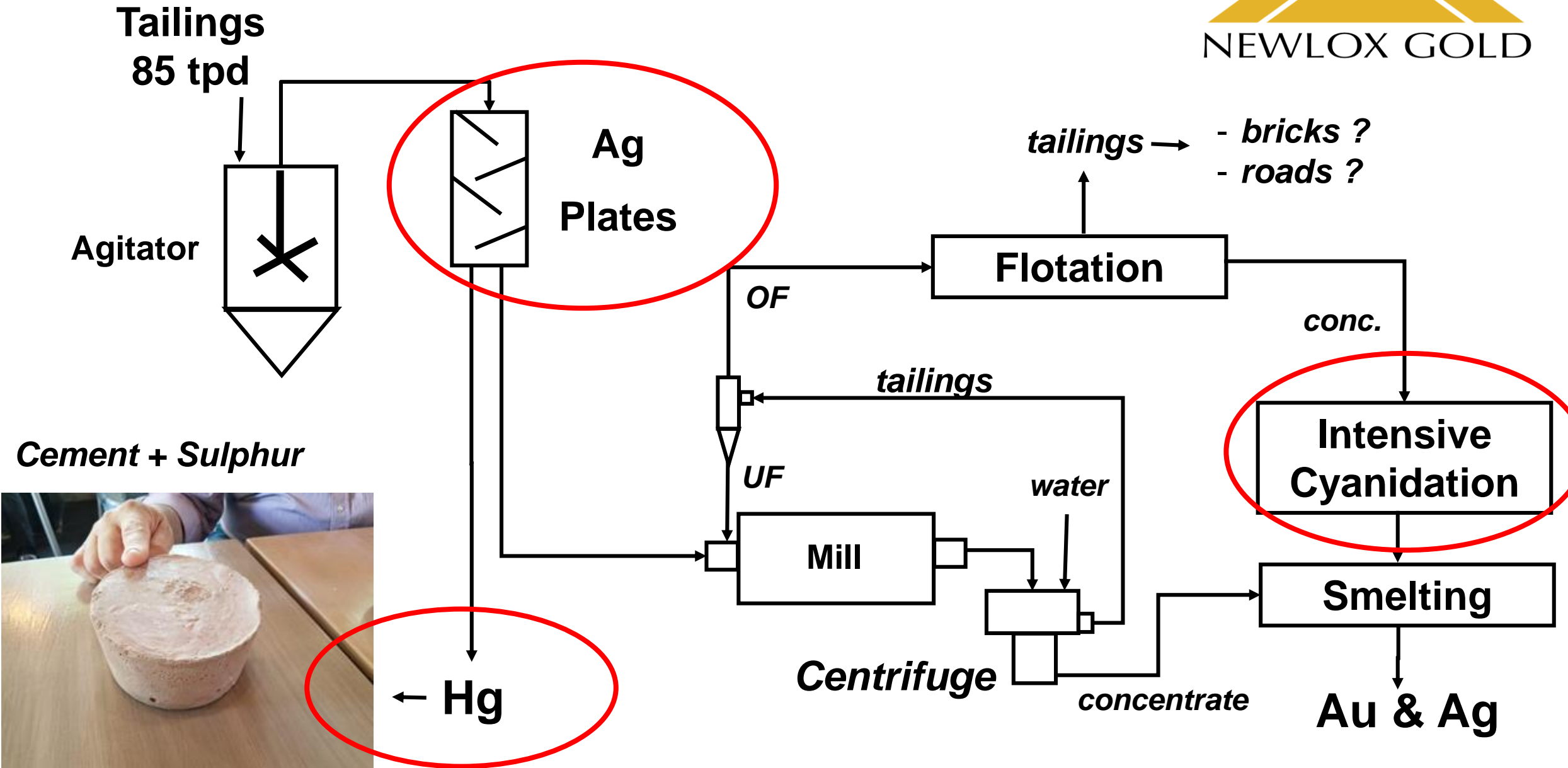
Plant for Re-processing ASGM Tailings



Costa Rica

Plant for Re-processing ASGM Tailings

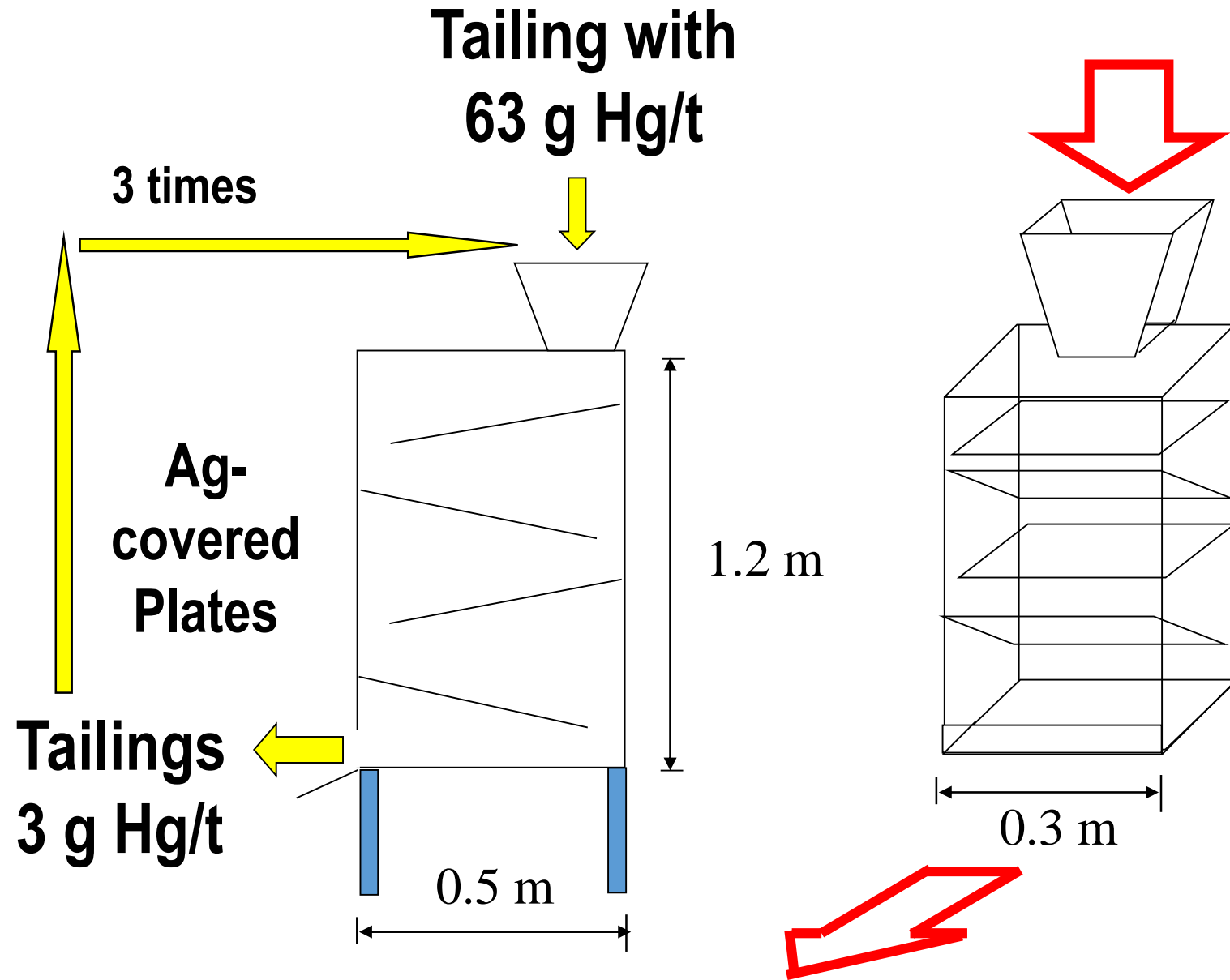
Costa Rica



What Technologies NERD is developing for Newlox plants?

- **Methods for leaching gravity and flotation concentrates**
- **Extract Hg before leaching**
- **Using Cassava**
- **Using DMSO**
- **Using Cyanide + Zn in a modified Merrill-Crowe**

Removing Hg from Contaminated Tailings



Lab prototype

Removing Hg from Contaminated Tailings



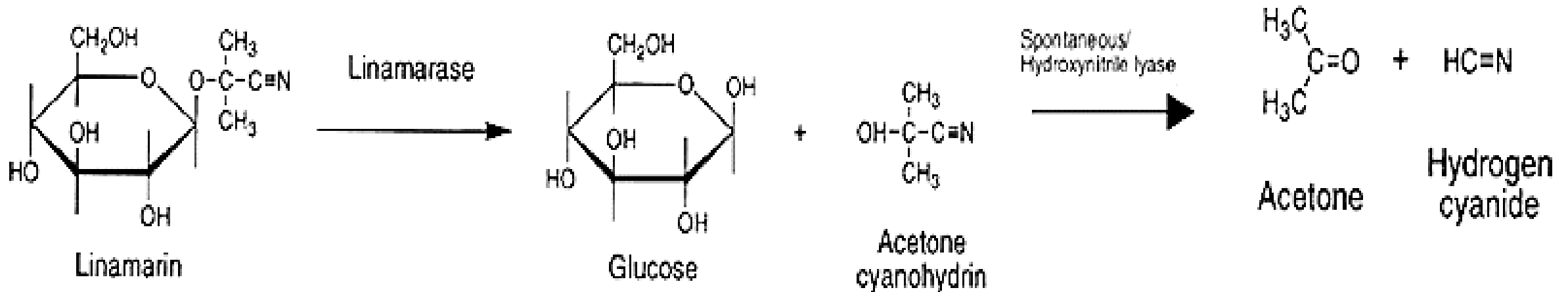
Cyanogenic Plants

- More than 2000 plants contain glucosides that can be converted to cyanide by hydrolysis (e.g. Bamboo, Sorghum, Lima Beans, Cassava, etc.)
- Some bamboo can have as much as 7.7 g of cyanide/g/kg of plant
- Some bitter cassava can have 2.4 g of cyanide/kg of plant



Cassava

- Around 98 species of cassava with different levels of the cyanogenic glucosides in which Linamarin is the main one
- Free cyanide is produced by hydrolysis of the Linamarin



Flour Production

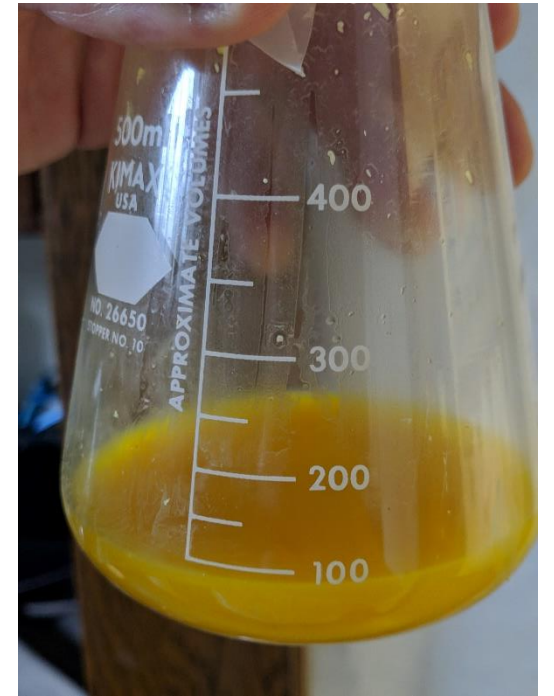
- In 2017, world cassava production was 292 million tonnes, of which Nigeria produced 20.4%, DRC 10.8%, Thailand 10.6%, Indonesia 6.52%, and Brazil 6.47%
- Main cassava use is to make flour or starch
- Bitter cassava is the main raw material
- The cassava is crushed and squeezed obtaining 30-35% w/w of liquid (manipueira)... “flour makers” use the solids to make flour by heating it at 120 °C



Peeling cassava in Brazil

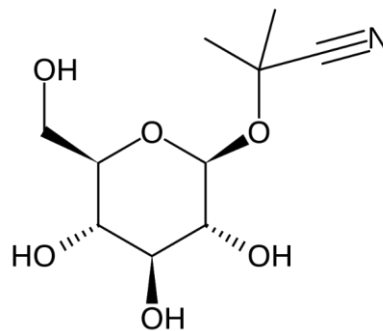
Manipueira

- The liquid extracted from cassava (“manipueira”) is rich in cyanide, reaching 2000 mg/L Free CN
- The cassava we eat has <20 mg of cyanide per kg of cassava
- Manipueira can be used to leach gold in small-scale



Bitter Cassava To Dissolve Gold

- Preliminary results in the UBC laboratory using a cassava with 267 mg/L free CN in 24 h resulted in 50-60% gold recovery from an artisanal gold sample
- Same conditions with pure NaCN reached 70% extraction
- Some preg-rob condition was observed, then the starch must be removed by flotation before using the manipueira



DMSO

(in collaboration with Dr. Akihiro Yoshimura from Chiba Univ., Japan)

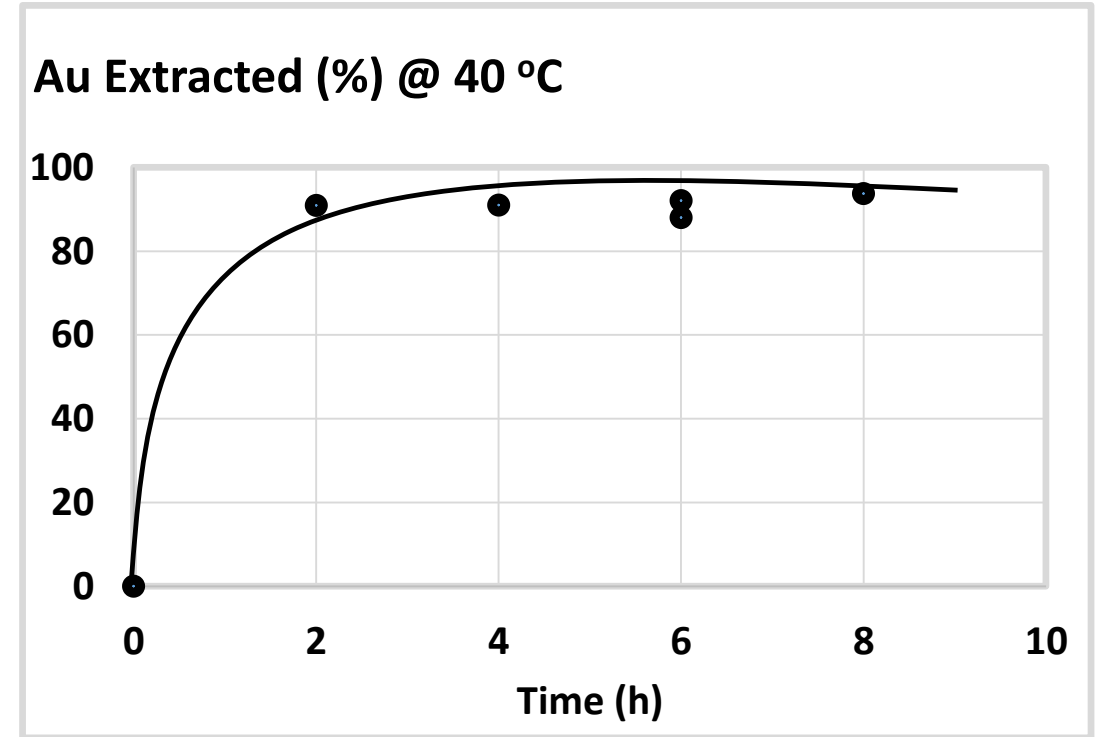
- DMSO (dimethyl sulfoxide) is used for cosmetics and paints
- A product with **very low toxicity** and a price compatible with sodium cyanide
- With a catalyst (copper salt) and sodium chloride
- Once gold is dissolved, it is precipitated with water or vinegar or lemon juice
- DMSO can be recycled
- Main disadvantage: Not too many producers of DMSO

DMSO

(in collaboration with Dr. Akihiro Yoshimura from Chiba Univ., Japan)

- Main Results, with amalgamation tailings:**

Temp (°C)	Time (h)	% Au extracted
20	24	92.63
30	8	95.58
40	8	96.51
50	4	93.56
50	6	96.72
60	8	95.94



More than 90% Au extraction in 2 h at 40 °C

Modified Merrill-Crowe

- Main problem of the Merrill-Crowe process to precipitate gold from cyanide solution (including cassava) is the need of clear (filtration) and de-aerated solution
- The idea is not to filter and not to use vacuum
- Tests using some socks with Zinc shavings and very low agitation of the pulp
- **Results** with Newlox material:
- 99.6% of gold removal from solution in 2 h from Hg-tailings (Hg was also removed)
- 99.3% of gold removed from Newlox ore

Conclusion

- **Technology is only a piece of the complex actions to eliminate Hg from AGM**
- **Technology is not a universal solution, it depends on the ore, the site, the skills, the capital, etc.**
- **Co-existence provides the best solution to remove processing from the artisanal miners' hands**
- **Processing Centers and small companies can use Hg-free techniques which are more efficient and cleaner**



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Thanks

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