

The Borax Method of Gold Extraction for Small-Scale Miners

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Background. More than ten million small-scale miners (SSM) worldwide use mercury to extract gold, releasing large amounts of the toxic element into the environment. Alternatives to mercury have been suggested over the years to little avail. A group of miners in the Philippines has demonstrated that borax, when used as a flux for smelting gold out of heavy mineral concentrates, is an effective and safer substitute for mercury.

Objectives. To present a basic comparison of the mercury amalgamation and borax methods of gold extraction for SSM.

Methods. Borax was added to milled ore to reduce the melting point of gold to a level accessible to SSM. The amount of gold captured, and the amount of mercury released into the environment, was compared to two common amalgamation methods: whole ore and heavy metal.

Discussion. The borax method appears to capture more gold, as well as eliminate the use of mercury. It is also less expensive. It is important to stop the use of mercury amongst SSM. However, health and environmental arguments alone are not enough to convince miners to switch. The argument of improving gold-capture rates while reducing costs is more compelling, and may help propagate the technique among small-scale miners.

Conclusions. Scientific research should continue in order to further establish the uses and limitations of the borax method.

Competing Interests. Leoncio Na-Oy provides training in the borax method of gold extraction.

Keywords. Borax, sodium borate, Philippines, pollution, health, gold mining, mercury, artisanal, small-scale mining, whole-ore amalgamation, heavy mineral amalgamation.

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Introduction

Mankind has been extracting gold from hard rock and alluvial deposits for more than three thousand years. Over this long history, many different methods have been used by enterprising miners. One of the earliest was a simple sheepskin left in a river to collect gold flecks within its fleece, leading to the myth of the Golden Fleece.

This method, along with many others, was eventually replaced by amalgamation, a process whereby mercury captures fine-grained gold by forming an amalgam with the precious metal. The method is easy to learn and does not require expensive equipment. Today, more than ten million artisanal and small-scale gold miners (ASGM)

worldwide extract gold using mercury. About 1400 tonnes/year of mercury is used by the ASGM sector, making this the largest source of the global mercury demand. Virtually all of the mercury is released into the environment.¹

An obvious drawback of this method is the toxicity of mercury.^{2,3} The health risk of mercury is well known today in many parts of the world, but in remote small-scale mining (SSM) communities that knowledge is still scarce.⁴ Gold extraction by amalgamation releases large amounts of mercury into the environment as metal mercury, which is later transformed to metholated mercury, a powerful neurotoxin that is readily

absorbed by biological tissue and toxic to humans and wildlife alike. This toxin enters the food chain and causes major health problems, including brain and nervous system damage leading to the retardation of mental and physical development. Children and developing fetuses are particularly vulnerable.^{4,5,6} Much of this is unknown to the miners, as is the fact that mercury released into the environment remains there and is capable of harming generations to come.⁷ However, even with education, environmental-impact arguments are often not enough to convince miners to swap to non-toxic gold extraction methods because these often require financial investments which most SSMs are not able or willing to make.⁸

Some SSM communities continue to practice the same method of gold extraction developed by their forefathers, whereas other groups are innovative and try to improve working techniques to increase gold recovery rates. An excellent example of this is a group of SSM in the Benguet province in the Philippines. Thirty years ago, a miner there discovered an environmentally benign way to recover gold from his heavy mineral concentrate: he found that by mixing borax into the concentrate, he was able to easily smelt the gold out.

Borax, also known as sodium borate, is a common component of many detergents and has many household-cleaning uses. It is classified as non-toxic, causes no known chronic health effects⁹ and is even found in some teeth-bleaching formulas.¹⁰ In a 2006 study by the United States Department of Agriculture, there were health risks found to neither humans nor wildlife except in the most extreme scenario involving direct consumption. Additionally, the study concluded that no acute or chronic health effects were associated with the use of borax. Negative effects included the potential for eye irritation when borax was not handled properly, but even this effect was mild and short-term.¹¹

The borax technique spread to fellow miners and presently around 15,000 SSM in a small area of Luzon, the main island in the northern portion of the Philippines, use this method exclusively. The mineral is inexpensive and easily available, and the miners have found that more gold is recovered through its use, as discussed below.

The objectives of this paper are to present a basic comparison of the amalgamation and borax methods of gold extraction for SSM, and to

Abbreviations			
ASGM	Artisanal and small-scale gold miners	SSM	Small-scale miners

propose that the borax method be further analyzed and promoted throughout global SSM communities. Over time, we hope to convince millions of miners around the world to use borax for gold extraction, significantly reducing global mercury pollution.

Methods

Gold capture, as well as the amount of mercury released into the environment, was analyzed for two amalgamation methods and the borax method.

The Amalgamation Methods

Mercury is used in gold mining because of its ability to bind to gold to form an alloy which helps separate the precious metal from rock, sand and other material. The alloy — or amalgam — is then heated, often in a shovel or metal pan over an open fire, to vaporize the mercury, leaving behind only the gold.¹

Amalgamation is carried out in different ways, including whole-ore and heavy mineral concentrate amalgamation. Whole-ore is the dominant method in the Philippines and Indonesia, whereas amalgamation of heavy mineral concentrates is commonly used in many African countries, including Tanzania and Sudan.^{2,3}

Of the two amalgamation processes, both of which are severely polluting, whole-ore results in greater environmental damage. In this method, mercury is added to rotating drums in which crushed gold ore

is ground up by hard metal rods or balls. The mercury also gets beaten during this procedure, and tiny (< 1 mm) spheres called “mercury flour” (Fig. 1) are produced. This “flour” gets mixed in with mine tailings and disposed of, usually by being dumped into nearby streams. This is a method by which mercury enters the local ecosystem and poisons those living downstream of the mine. Gold captured by the mercury flour is not recoverable, and this regular loss of mercury represents a significant financial loss for the miners.

Some SSM are aware of the formation of mercury flour but argue that gold remaining in the tailings can be captured using cyanide. Unfortunately,



Figure 1 — Mercury flour as <1 mm spheres in tailings. Spoon is ~3 cm long (This and all photographs credited to P. Appel, 2012)

this is not the case: cyanide does not extract significant amounts of gold locked in mercury flour. In order to demonstrate this to miners in Tanzania, samples of tailings were collected in 2009 before and after cyanidation. The results in Table 1 clearly show that only a fraction of gold was captured by cyanidation, and high-grade tailings were discarded.² Analytical work for this demonstration was performed at Activation Laboratories in Canada using the Instrumental Neutron Activation Analysis method.³

The process of amalgamation of heavy mineral concentrates is slightly different. A heavy mineral concentrate is produced from ground-up ore to which mercury is added. Only about one gram of mercury is required to extract one gram of gold. However, tailings from this process are often repeatedly run through the ball mills. Each time more auriferous, or gold-laden, mercury flour is produced. Though less mercury escapes by this method, this type of amalgamation is also a significant source of pollution and loss of gold. Table 2 shows analysis of tailings in Tanzania which had been processed but still contained valuable gold and toxic mercury.³

It is clear that whichever of the two amalgamation methods is used, it is a lose-lose proposition for both miners and the environment.

The Borax Method

Not only did the Benguet SSM introduce the borax method of gold extraction as a tool, they also fine-tuned each step of the process from crushed ore to gold pellet. Their method is as follows:

The first step after crushing the ore is milling. This takes place in metal drums with hard metal rods or balls.

Sample No.	Location	Before Cyanide	After Cyanide	Gold g/ton	Mercury g/ton
494855	Sibutad	+		16	250
494856	Sibutad		+	14	200
494857	Casalugan	+		14	120
494858	Casalugan		+	13	73

Table 1— Gold and mercury content of tailing samples before and after cyanidation

Sample No.	Gold g/ton	Mercury g/ton
OT-1A	6.67	1.94
OT-1B	6.85	2.15
OT-1C	5.20	2.21
OT-2A	7.51	0.58
OT-2B	5.05	<0.01
OT-2C	9.02	<0.01

Table 2 — Samples of tailings which have been processed once or twice. The contents of gold and mercury shows that there is a major loss of precious metal and a large source of mercury pollution due to inefficient processing. Samples are from Itumbi, central Tanzania

No mercury is added. After milling, the ground-up ore is flushed into a sluice. There are a variety of sluices used from one country to the next and even from one SSM community to another. The system shown in Figure 2 is regarded to be the most efficient, but simpler sluices are often seen in other countries such as Tanzania.

The material in the sluice runs down over a carpet in a chute (Fig. 2), the modern equivalent of the ancient fleece. The best material for this is felt, which traps heavy minerals contained in the slurry. When the carpet is loaded, or full of heavy minerals, it is washed in a bucket (Fig. 3). The heavy minerals collected from the carpet are concentrated with a gold pan. A little soap added to the water in the pan helps reduce surface tension so gold flakes sink to the bottom instead of floating away into the tailings. This washing has to be thorough in order to produce a high percentage of gold in the concentrate (Fig. 4).



Figure 2 — Sluice and felt-covered chute

The heavy mineral concentrate is placed in a small piece of plastic with borax and a few drops of water



Figure 3 — Loaded felt is “washed” to get the captured heavy minerals into the bucket

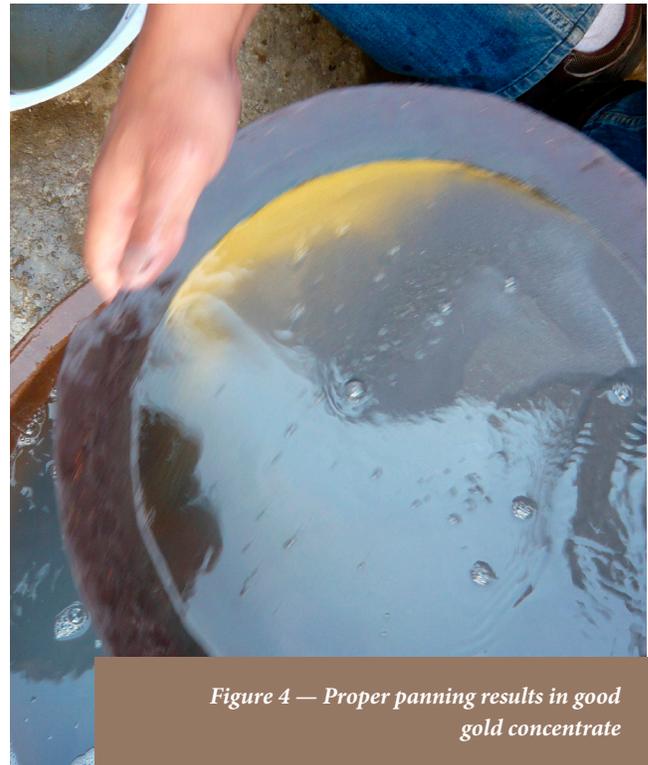


Figure 4 — Proper panning results in good gold concentrate

(Fig. 5). The plastic is placed in a clay bowl together with several pieces of charcoal, which are then ignited. A hand-powered or electric blower fans the flames, increasing the temperature of the fire. After a few minutes, the heavy minerals melt and the gold flows to the bottom (Fig. 6). The success of this method is due to the fact that borax reduces the melting point of gold (1,063°C), bringing it down to a level accessible to ASGM with limited technology.

Results

The Borax method appears to have three major advantages over amalgamation methods:

- Mercury, a known toxin, is not used;
- Gold capture is improved;
- The borax method is cheaper than the amalgamation method.⁹



Figure 5 — Gold concentrate with borax and water ready for smelting

Discussion

Globally and regionally, it is of paramount importance to stop the use and release of mercury amongst SSM. However, health and environmental arguments alone are not enough

to convince miners to switch from a known technology — mercury amalgamation — to an unknown one, borax. This is because most SSM put a greater emphasis on the economic survival of their families and community than personal health

or the abstract idea of global welfare. However, if it can be demonstrated that miners recover significantly more gold by using borax instead of mercury without significantly increasing effort or cost, we predict most SSM will adopt the borax method.

It should be noted that the borax method is not appropriate for all types of gold ores. Some ores, perhaps those with very fine grain sizes or rich in sulfur, may not be amenable. Before initiating teaching-and-training courses for SSM, the gold ore in those particular communities need to be tested to see whether the borax method is appropriate for that locale. More research in this area needs to be done and is outside the scope of this discussion.

The Example of Kalinga, Northern Philippines

The borax method is not well known in other parts of the world, or even in other mining communities within the Philippines. To expand this expertise in that country, a project was initiated in 2011 in two other AGSM communities with the following components:

- Teaching and training SSM to use borax instead of mercury;
- A baseline survey of knowledge of mercury problems among SSM and health providers in selected communities.

The first teaching-and-training session took place in the Kalinga area of Luzon. The instructor was the second author of this article, who has successfully used the borax technique for decades. A demonstration of the process was arranged as follows:

- 16 sacks with 50-kg of ore were randomly taken from several days of gold-ore production. The random



Figure 6 — Heavy mineral concentrate mixed with borax has melted and the gold has flowed to the bottom of the clay bowl

selection was used to compensate for the heterogeneity of gold content in the ore.

- The Kalinga miners processed a sack with their usual amalgamation technique. They recovered 1.2 grams of gold.
- A second sack was then processed using borax. Recovery jumped to 3.5 grams of gold.

This process was repeated. A total of 8.4 grams of gold was recovered from 7 sacks using the mercury amalgamation method. Using the borax method, a total of 23 grams of gold was recovered from the remaining 7 sacks of ore.

The miners of Kalinga realized through this demonstration that they could potentially recover as much as three times as much gold by using borax compared to mercury, for less money and no additional effort. Borax is now in common usage in this community.

Further Spreading the Message

It is unclear why the borax method has not spread from northern Luzon

to other parts of the Philippines. However, a three-year Danish government-funded teaching-and-training project has started to disseminate knowledge of the process, using the demonstration model. Instead of focusing solely on environmental and health benefits, the project initially highlights the economic benefit for the SSM. By doing a side-by-side comparison of recovery rates of the traditional mercury method and borax, it is clearly evident to miners that they can earn much more gold by using the borax method. Furthermore, the method does not take longer nor does it require investment in new technology. The Danish project aims to convince 1,500 SSM throughout Luzon to adopt the borax method. The project should then be replicated in other regions in the Philippines and around the world.

It is hoped that the borax method will spread as more SSM are introduced to it. Another way of broadcasting knowledge of the borax method is a video, produced in 2011 by Heinemann Media, Denmark, explaining the method in English and

Tagalog. There are no copyrights on the video and it can be downloaded for free at <http://www.geus.dk/borax>.

Conclusions

Although scientific research should continue in order to further establish the uses and limitations of the borax method, current evidence strongly supports that this technique, where appropriate, is environmentally benign compared to mercury and improves gold extraction rates. Borax is also inexpensive, readily available and the method is easy to learn.^{12,13} By switching from mercury to borax, SSM can earn more money and reduce their contribution to the global mercury pollution.

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