THE LUGAW-LUGAW METHOD

>>Understanding the Cyanide-in-Drum Method of processing gold in Masbate

NRDC

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>>CONTENTS

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2. Prevent toxic trade in products, wastes, and technologies, particularly trade from developed to developing countries in the Asian region through the promotion of self-sufficiency in waste management, clean production, toxics use reduction, and other sustainable and equitable practices or methodologies.
3. Reach out and work in solidarity and partnership with allied groups locally and regionally in Asia, striving to instil a broader consciousness of the interrelatedness of each community, each country, within the region and to uphold our collective fundamental human right to life and to live in a healthy and peaceful environment.
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>>THE BIRTH OF THE LUGAW-LUGAW METHOD

INTRODUCTION

Gold is a rare element. The average concentration of gold in the Earth's crust is 0.004 g/tonne. A gold deposit only becomes interesting for economic exploitation if the ore grades are above 0.2 g/tonne, with rich deposits reaching 10 g/tonne of rock (Veiga, et al., 2006) . However, the extraction of gold does not depend solely on the gold grade but also on the mineralogy of the gold (i.e. how the gold occurs in the ore), and the access and infrastructure of the site. Given the rarity of the element, as well as the difficulty posed by its extraction, a variety of gold mining techniques and methodologies has been developed and utilized.

One of these mining technologies is gold cyanidation, also known as the cyanide process. It is a metallurgical technique for extracting gold which employs the ability of cyanide to form a water-soluble coordination complex with gold (Rubo, Kellens, Steier, & Hasenpusch, 2006). Carbon-in-Pulp (CIP) and Carbon-in-Leach (CIL) are two of the most common gold cyanidation processes applied in large-scale and small-scale gold mining operations in the Philippines and around the globe. Both methods generally employ massive stepped tanks aligned in a column whereby gold is dissolved from an ore slurry (pulp) through a chemical process which incorporates agitation, oxygen and cyanide (Stange, 1999). The use of cyanide, however, has been controversial due to its potential toxic effects on the workers, the people living in the immediate community and the environment. Direct exposure to cyanide-contaminated tailings, for instance, has resulted in the killing of fish, birds, and other animals (Veiga, et al., 2006). Even though there are a very few cases of people being poisoned from the use of cyanide for mining gold, the potential for such accidents still demands that gold miners use cyanide in a safe and environmentally-responsible manner. Generally, the use of cyanide in mining has been popular because of the following reasons. (Veiga, et al., 2006):

- Only a relatively small amount of cyanide is needed to recover gold-- usually less than one kilogram of cyanide per tonne of rock. Cyanide is also measured in grams per liter of water or slurry.
- Cyanide is very selective, leaching gold and only minor amounts of other minerals in the ore.
- Cyanide leaches coarse and very fine gold, as well as gold that is attached to the rock. This makes it suitable for processing waste tailings from sluicing methods to extract fine or micro gold.
- Cyanide and cyanide-treated material can be effectively and cheaply destroyed to minimize impacts and risks. Additionally, residual cyanide naturally degrades in the environment through the exposure of UV (sunlight) and at the pH of natural waterways. Cyanide can either be immediately converted into less toxic forms or destroyed into carbonate and ammonium.
- The risk of cyanide poisoning can be minimized through correct and responsible use. Cyanide, unlike mercury, does not accumulate in animals or plant life.

The disadvantages of cyanide leaching are:

- At high concentrations and direct exposure, it will kill fish, birds, and mammals including humans.
- Cyanide reacts with mercury and other heavy metals, as cyanide is sometimes used on tailings that are contaminated with mercury. This produces soluble chemical compounds that are easily transported with water, thereby increasing mercury's mobility and spreading mercury contamination to large areas to bioaccumulate.
- Cyanide also requires careful training on the management, implementation of guidelines and monitoring during the process to ensure both effectiveness and safety.

Though effective and economical, cyanide use and transportation present significant environmental risks that should be considered in any gold mining operation. As a result of these environmental concerns, some states in the USA have banned the use of gold cyanidation. In response, the gold mining industry has promoted adherence to a voluntary cyanide management code, which implements strict independent audits of signatory companies. Aside from the safe management of cyanide during production and transportation, strict regulations during gold recovery and on mill tailings and leach solution should be followed (International Cyanide Management Code). Large scale mining operations should also follow requirements relating to financial assurance, accident prevention, emergency response, training, public reporting, stakeholder involvement and verification procedures. (Ground Truth Trekking, 2012). The challenge now is for small-scale miners to achieve this same level of control and monitoring without the use of sophisticated and expensive equipment.

The application of gold cyanidation processes in small-scale mining operations imply not only environmental impacts but also a shift in economics. As used in the large-scale mining industry, the volume of ore materials or tailings that undergo CIP and CIL circuits normally amount to at least 100 sacks per batch or more. This poses a concern for miners who desire to apply these techniques in small-scale mining operations but do not have the operational capital to gather the huge volume of materials for processing. To address the small-scale miners' need to process small amounts of tailings or fresh ore materials through gold cyanidation, the *lugaw-lugaw* or cyanide-in-drum (CID) process was developed. The term lugaw-lugaw stems from the semblance of the consistency of the milled slurry to the local rice porridge called lugaw. Being a small-scale version of CIL, CID allows a minimum of 1 sack of ore material per cycle, using increased amounts of cyanide and activated carbon to ensure gold extraction and to achieve net profit. The smooth assimilation of such technique was made possible because no modifications were made to the existing mining facility set-up commonly used in sluicing and mercury amalgamation. Since most artisanal and small-scale miners need to earn profit on a daily basis, the development of the *lugaw-lugaw* method appears to be a welcome blessing for the mining community of Aroroy, Masbate, where this method was born.

Mr. Isagani Rapsing, a small-scale miner and a CIP plant owner, pioneered and developed the CID process in Masbate. Prior to full operations, he employed trial-and-error methods to determine the amounts of materials and time duration that will be suitable and effective in extracting the gold from the initial materials.

Currently, CID operations in the municipality are concentrated in *Barangay Tinago, Aroroy, Masbate*. Mr. Rapsing willingly and freely trains other small-scale miners in their community on the CID process, which enables them to adopt it in their own operations-- eventually catapulting the proliferation of such method in the barangay or village. These miners use the CID method to extract fine or microscopic gold from fresh ore materials directly coming from tunnelling, or from tailings produced through either mercury amalgamation or gravity concentration methods. CID operations are highest during "dry" seasons, when miners are unable to extract fresh ore materials from tunnels and opt to process their previous tailings to earn a living. Aside from the easy transmission of knowledge and know-how on the process in the community, the increasing price of mercury and the eventual` enforcement of the Executive Order (EO) No. 79 which bans the use of mercury in artisanal and small-scale gold mining (ASGM), may contribute to the shift from mercury-use to gold cyanidation in the province.

OBJECTIVES of the STUDY

The objective of the study is to provide a close look at the lugaw-lugaw method—a mining innovation which derives its origins from the CIL processing of gold-bearing ores, and document the process.

The study will elaborate on (1) the materials and equipment used and their specifications, (2) the rationale behind the processing stages, (3) the parameters which affect the CID circuitry, and (4) the possible implications of the use of cyanide and other mining methods to the dynamics of the people's livelihood.

>>PROCESS RATIONALE: THROUGH THE LENS

SCHEMATIC DIAGRAM

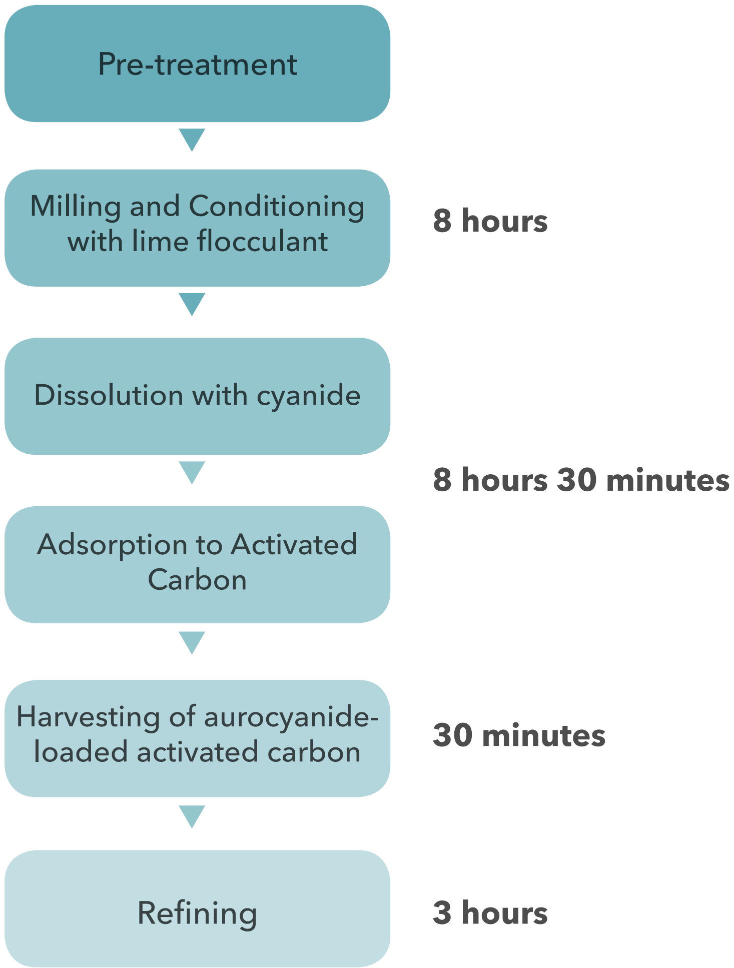

Figure 1. Process diagram of the *lugaw-lugaw* method

The CID method of gold processing is a condensed version of the CIL circuit, characterized by the smaller volume of materials processed and the overlapping of the dissolution and adsorption stages which normally makes the CIL method appear longer and more time consuming. Though smaller in scale, the amount of materials used is amplified to ensure that the finer gold particles from the batch are extracted and captured. The method takes about 20 to 24 hours in total, from grinding and crushing of the ore material to extraction of the gold concentrate, which immediately renders the miners and operators their net profit at the end of the mining activity.

The method is applied on either newly-mined ore materials, or tailings produced from concentration or mercury processes. Fresh ore materials that are visually-assayed and are found to contain high concentrations of microscopic gold particles immediately undergo the cyanidation process to achieve profit. On the other hand, miners also process the tailings from concentration or mercury methods to capture the fine particles of gold that were not extracted by the initial gold extraction procedures to maximize the operational capital exerted on acquiring the initial batch of ores from the tunnels.

The equipment and materials are cited in the order of their use in the *lugaw-lugaw* process. The list also describes the function and importance of each in the process, and how each contributes to the prerequisite conditions needed for the extraction of gold through cyanidation. There are a variety of innovations and improvisations in most of the equipment utilized, however, the study opted to focus and document only those that were used during the actual study.

EQUIPMENT

Figure 2. Small-scale mining facility which operates using the lugaw-lugaw (CID) process. This facility is composed of 4 rodmills attached to a single shaft by rubberized belts.

1. Rod, pebble or ball mills. Ball, pebble and rod mills are cylindrical rotating shells which are mounted on bearings and filled up with up to 40% by volume of a grinding medium such as steel balls, rods or hard pebbles (Veiga, et al., 2006). Small rods are used best for fine grinding, while the big rods help break the larger chunks of ore.

The mining facility used to document the *lugaw-lugaw* process has 4 rod mills, all of which are connected in a single shaft via rubberized belts. The F6 horsepower engine runs using diesel and is attached to a drum filled with water to prevent overheating. Each rod mill has a diameter of 20 in and length of 30 in and can load ½ to 1 ½ sacks of ore material, ranging from 30 to 90 kilograms. Given the size of the rod mill, an equivalent of 30 kilograms of grinding medium was needed. These rods vary in sizes and lengths to ensure optimal grinding. Two of the four rod mills were used to process the ore samples.

- Rod mill A used 4 pieces of 20 inch long rods, while;
- Rod mill B used 8 pieces of ½ to 1 ¾ inch rod sized combinations

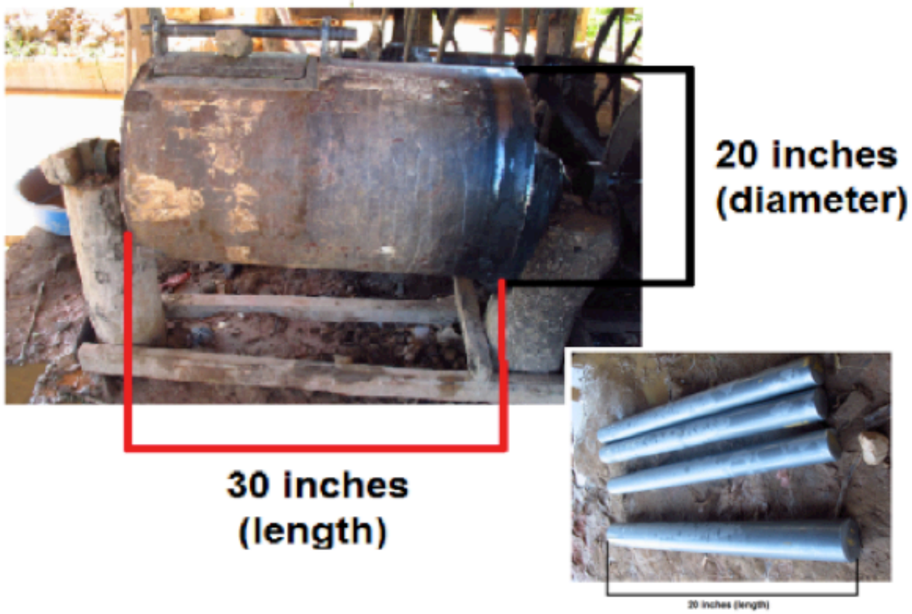

Figure 3. Dimensions of a Rodmill. This rodmill can load up to 90 kilograms of ore material and needs at least 30 kilograms of grinding medium.

Since these rods are used constantly in mining operations, their sizes and lengths have been impacted by the forces related to grinding and crushing during milling. However, the most important factor, the weight of the rods, is taken into account by using combinations of different rod diameters and lengths.

2. Tub or Tailings pond. Tailings ponds are concrete dam-like structures used as catch basins for waste water produced in any gold mining operations. In the case of the *lugaw-lugaw* method, the waste water contains the pulp from milling, as well as cyanide dissolved in an alkaline solution. The size of the pond depends on the available space in the mining facility, with most miners preferring to maximize the area to anticipate the volume of waste water from continuous gold processing batches and to prevent the overflowing of the pond.

Figure 4. Tub. The tailings pond or Tub serves as a catch-basin for waste water from mining operations. Bigger dimensions for the tub prevent overflowing and ensure continued mining cycles.

The tailings ponds are usually located under direct sunlight to ensure the natural decomposition of cyanide into its non-toxic forms. Since the waste pulp may contain up to 10% of free gold not adsorbed by the activated carbon, some mining operators prefer to further refine and process the tailings, while others put the recovered tailings in sacks, either to sell them to other mining operators or to use them as barricades or fences and additional building materials.

3. Improvised screen mesh. An improvised screen mesh acts as a filter to capture the aurocyanide-loaded activated carbon (gold-cyanide complex) from the pulp load. It is usually made up of stainless steel, with filter sizes ranging from 20 to 30 mm to accommodate the singular pellet size of the carbon used.

4. Improvised grill. The improvised grill is made from an old rod mill covered with stainless steel mesh. This was where the aurocyanide-loaded activated carbon is burned using coco shell charcoal. An electric fan or ventilator was used to ensure constant supply of oxygen to the fire. After burning with charcoal, the screen mesh was also used to segregate the subsequent ash and charcoal pellets to retrieve the processed metal.

Figure 5. Improvised Grill. Old rodmills are recycled and used as grills for burning the activated carbon using coco shell charcoal

5. Acetylene blowtorch. The blowtorch is used for smelting the metal concentrate and the gold concentrate. A separate furnace set-up in the mining facility is built to accommodate several batches of gold refining.

Figure 6. Furnace set-up. Acetylene blowtorch is used to smelt the metal concentrate with borax. Ceramic pots are used during smelting because of its capacity to tolerate high temperatures.

6. Ceramic pot or palayok. Since ceramics can tolerate the high temperatures maintained for smelting, ceramic pots are used when the concentrated metal is blowtorched to retrieve the gold from other impurities.

MATERIALS

1. Gold-bearing ore materials. Gold-bearing ores can be generally divided into two types: (1) free milling ores and (2) refractory ores. Although, there are some ores that have a combination of both. Free milling ores consist of sulphide and oxide ores, which require no additional pre-treatment after milling and can achieve recovery of up to 98% when a properly administered cyanide recovery method is employed (The Shark Group, 2000). However, physical pre-concentration methods such as gravity or flotation can also be effectively used thus reducing the overall mass that is treated with chemicals. Refractory ores, on the other hand, are harder to extract -- usually yielding gold less than 80% by standard cyanidation processes. The reasons for poor recovery may be chemical or physical in nature (Gray, 1999).

CHEMICAL	PHYSICAL
Insoluble gold tellurides	Encapsulated gold (Pyrite, Arsenoyrite, Silica)
Cyanicides or cyanide-consuming ores (Pyrrhatite, Covellite, etc.)	Gold alloys (Antimony, Lead, etc.)
Oxygen-consuming ores (Sulphide ions, Ferrous ions, etc.)	Gold coated with a thin film (Iron oxide, Silver chloride, etc.)
Not enough cyanide or poor chemical kinetics.	Gold preg-robbing (carbonaceous materials, non-conditioned carbon and clay)

Figure 7. Ore material for documentation. Two sacks of gawds, a type of ore commonly found in Aroroy, Masbate) were used. This particular sample contains 1 gram of metal, based on the assay done prior to the documentation process.

Pre-treatment processes, such as thermal, chemical, biological treatments and pressure oxidation (acid or alkaline) are developed to facilitate higher gold recovery. In small-scale mining operations, physical treatments such as increased grinding periods and pre-aeration are done to address the difficulties brought about by refractory ores.

Solid ore materials acquired through blasting in tunnels are manually (using a mallet or hand-driven grinder) or mechanically crushed until it is pebble or gravel-sized. The *lugaw-lugaw* method run time for this type of ore consists of 6 to 8 hours of milling and conditioning with lime. Sandy type ores have a muddy pulp consistency, thus, no prior crushing or grinding is needed. However, a higher volume of water is required during milling and conditioning with lime, which typically occurs for about 3 to 5 hours. Initially, the ore material can be assayed to determine the expected gold concentration and to distinguish the efficiency of the extraction procedure used. The ore used is estimated to have 17 g of Au/tonne, based in a visual assay conducted prior to the CID run.

2. Lime (Calcium hydroxide). Lime is added in the slurry for two important reasons: (1) to prevent the creation of toxic hydrogen cyanide and, (2) to create a suitable pH environment for the adsorption of aurocyanide (gold-cyanide) onto the activated carbon.

At a pH of 9.3-9.5, CN- (free cyanide ions) and HCN (the acutely toxic hydrogen cyanide) are in equilibrium, with equal amounts of each present in the solution. At pH 7, over 99% of the cyanide will exist as HCN while at pH of 11, over 99% of the cyanide remains in solution as CN-. HCN is highly soluble in water, but its solubility decreases with increased temperature and highly saline conditions (International Cyanide Management Code).

Though increased pH is favorable for safety reasons, pH conditions above 10.5 have a negative effect on the ability of cyanide to dissolve gold as well as the rate of aurocyanide adsorption onto the activated carbon. This drop in adsorption rate can be explained by the competition of hydroxide and aurocyanide ions for active sites on the carbon (Gray, 1999). Thus, a pH of 10.5 should be maintained through regular measurement and process control. The pH of the slurry can be checked prior and during the process using a pH paper, which miners do not typically conduct. Small-scale miners following *lugaw-lugaw* operations have learned to estimate the amount of materials needed through the experience they have gathered in the field. Depending on the type of ore, the amounts of cyanide, carbon and lime used are learned through their empirical observations from previous runs of the method.

3. Activated Carbon. Activated carbon is a generic term for a family of highly porous carbon-based compounds, none of which can be characterized by a structural formula or chemical analysis. It is produced from a wide variety of raw materials such as peat, peach pits, wood char, bone char, coconut shells, carbon black, etc (Deithorn & Mazzoni). The most important physical properties of activated carbon are the number and size distribution of the pores, bulk density, dry impact hardness, wet abrasion resistance and particle-size distribution. However, there are three properties common to all types of activated carbon which describe its high adsorptive ability (Gray, 1999):

- A large specific surface area resulting from small pore diameters
- A partially oxidised surface
- A charred (carbonised) organic substrate

The pore structure and surface area of activated carbon is developed during the carbonisation and activation processes. Although the pores are usually cylindrical or rectangular, they can occur in a variety of shapes. Pores can be classified according to three distinct groups based on their pore diameter (Gray, 1999):

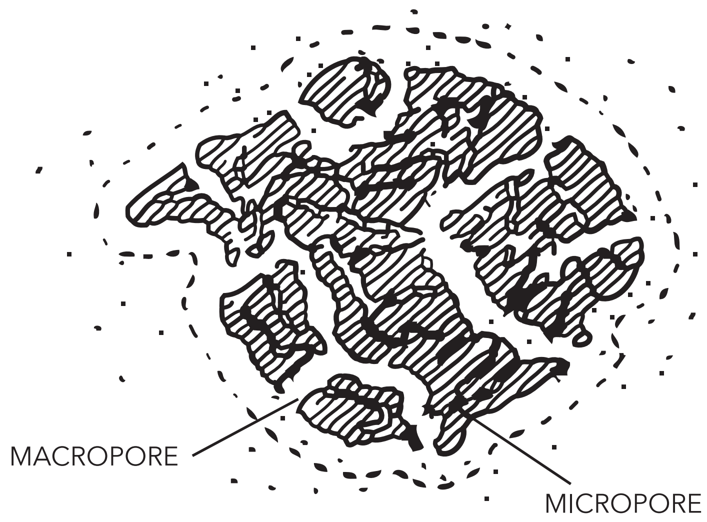

Figure 8. An illustration of the pore structure of activated carbon

- Macropores (>25nm) are channels which are determined by the cell structure of the original carbon material. They provide rapid access to the meso- and micropores where actual adsorption takes place.
- Mesopores or transitional (1 to 25 nm and account for 5% of the internal surface area) are situated between graphite-like microcrystallites which are also formed by activation perpendicular to the plates.
- Micropores (<1nm and account for 95% of the internal surface area) are developed during activation, when graphite-like microcrystallites are affected.

Physical adsorption is the primary means by which activated carbon works to extract gold from the slurry. Its highly porous nature provides surface area where the adsorbate or the liquefied metal (gold, copper, silver, manganese, etc.) binds. This occurs because all molecules, especially those at the surface of a solid, exert attractive forces where other molecules adhere to (Deithorn & Mazzoni). This differentiates adsorption from absorption-- the former involves the binding of molecules or particles to a surface, while the latter involves the filling of pores in a solid. The exact nature of the bonding depends on the details of the species involved, but the adsorption process is generally classified as physisorption (characteristic of weak van der Waals forces) or chemisorption (characteristic of covalent bonding). It may also occur due to electrostatic attraction (Ferrari, Kaufmann, Winnefeld, & Plank, 2010).

4. Cyanide (Sodium Cyanide). Cyanide is one of the few chemicals that can facilitate the dissolution of solid gold into a stabilized gold species in a solution or slurry (liquefaction) by forming stabilized gold species in solution (International Cyanide Management Code). The resulting complex, aurocyanide, undergoes activated carbon adsorption.

Cyanide is very reactive and can form simple salts with alkali earth cations (i.e. sodium, calcium, etc.) and ionic complexes of varying strengths with numerous metal cations (i.e. gold, silver, etc.). The stability of such complexes depends on: (1) the cation or the strength of the cyanide complex and (2) the pH condition of the solution (International Cyanide Management Code). The salts of sodium, potassium and calcium cyanide are quite toxic, as they are highly soluble in water and readily dissolve to form free cyanide. Mining operations use cyanide in its solid form or dissolved NaCN (sodium cyanide) or $Ca(CN)_2$ (calcium cyanide). Although metal-cyanide complexes are much less toxic than free cyanide, their dissociation releases free cyanide as well as the metal cation.

Cyanide complexes with gold, mercury, cobalt and iron are very stable even under mildly acidic conditions. The stability of cyanide salts and complexes is pH dependent, and therefore, their potential environmental impacts and interactions can vary. Some times, miners measure the free cyanide (an operational parameter) in the slurry through titration with KI (potassium iodide) and $AgNO_3$ (silver nitrate). This is typically done when processing ores from a new tunnel, and is rarely done in succeeding cyanidation operations for ores from the same mine. However, it should be noted that this method cannot determine cyanide complexes such as WAD or Total Cyanide that are typically used in environmental and tailings monitoring.

5. Borax. Borax, also known as sodium borate, sodium tetraborate, or disodium tetraborate, as a fluxing and refining agent, functions by forming cross-links or network linkages in the concentrate (20 Mule Team Borax, 2012). In doing so, it:

- Forms a lighter, insoluble, liquid layer which protects the molten metal from air oxidation, which increases the affinity of the gold particles and facilitates their "grouping" together;
- Provides a liquid phase for contaminants to migrate to. The linkages serve to sequester oxophilic metals such as iron, magnesium, aluminium, etc., which further remove gold impurities;
- Modifies the melting point and viscosity of the slag which makes the slag fluid and "pourable", and thus much easier to separate from the gold.

6. Nitric Acid. Since gold and silver are often extracted from the same ores and are chemically similar, nitric acid is used in gold parting.

PROCEDURE and RATIONALE

Note: *The members of the documentation team wore the proper personal protective equipment (PPE) while filming since only specifically-designed HCN masks can protect workers from CN vapors. However, in the normal set up, miners tend to wear a common dust mask during (1) the application of sodium cyanide in the slurry, and (2) smelting stages.*

(Step 0) Comminution (Optional). The length and effort applied on the grinding process of ore materials depend on the type of the ore and the type of gold in the ore. The ore is fed in a manual or mechanized grinder to disintegrate the rock and liberate gold from other gangue minerals. Crushing reduces the physical size of large rocks, exposing more surface area of the rock. This frees any gold that may be in the rock and increases the probability of obtaining the gold through the cyanidation process. Comminution involves two phases: (1) crushing to produce coarse ores, and (2) grinding to produce finer particles. If the ore material contains both coarse and fine gold particles, miners opt to separate the coarse gold first through sluicing or mercury amalgamation process. The subsequent tailings products containing fine-sized gold particles can then be processed under cyanidation. Verification of the grain size in the field is done by vision and by touch to determine if grinding time must be increased. The ore material used in the study was sufficient in size according to the customary process of the local miners and did not need to undergo comminution. This is also the same scenario when processing tailings.

(Step 1) Milling and Conditioning with Lime. The mill is loaded with 2 parts of ore, 1 part of water and 1 part of steel balls/rods, and allowed to run for several hours. The study set-up used 1 sack for every rod mill (approximately 60 kilograms each) of sandy loam (or sugar vein) ore material. Sandy type ores has a muddy pulp consistency, thus, no prior crushing or physical treatment is needed. However, it requires a higher volume of water during milling and conditioning with lime. Typically, the milling stage runs for 3 to 5 hours but can be extended up to 8 hours to ensure the uniformity and consistency of the ore material. Through visual assay, the ore material is estimated to contain 17g Au per tonne.

Loading of ore materials and equivalent rods (grinding medium) | Addition of lime flocculant (1 kilogram per rod mill) | Addition of water

Figure 9. Loading of materials into the rodmill.

In the CIP method, 1-2 kilograms of lime is required per tonne of ore. The CID process also utilizes the same amount of lime, however it is applied to only 60 kilograms of ore material. The increased amount of lime neutralizer immediately creates an alkaline solution–thus preventing the formation of toxic gas once the cyanide is poured in the slurry. The exact amount of lime that is required will depend on the properties of the ore and can be checked by measuring the pH of the pregnant solution using litmus paper or pH paper. However, this is a process control that miners rarely conduct in the field.

(Step 2 and 3) Dissolution of gold with cyanide and Carbon Adsorption

After crushing and/or grinding the ore, cyanide was added and used to leach the gold from the slurry, dissolving it into the water. To leach the gold, there are four components required: water, cyanide, air (oxygen) and alkalinity (high pH). If one of these components is missing, the process will not be effective in extracting and liquefying the gold. The main source of oxygen is the water, along with the ambient air composition inside the drum. Cyanide leaching of gold (and silver) is described by the following chemical reactions:

$$4\,Au + 8\,NaCN + O^2 + 2\,H_2O \Rightarrow 4\,Na[Au(CN)_2] + 4\,NaOH \text{ (Elsner's equation)}$$

$$Ag_2S + 4\,NaCN + H_2O \Rightarrow 2\,Na[Ag(CN)_2] + NaSH + NaOH$$

Where Au=gold; Ag=silver; Na=sodium; CN=cyanide; O_2=oxygen; H_2O=water; OH=hydroxide; SH-sulfide (International Cyanide Management Code)

Loading of sodium cyanide (0.50 kilogram per rod mill)

Figure 10. Addition of cyanide. Sodium cyanide (NaCN) is called puto-puto in the local community because of its semblance to the local rice cake.

The CID method utilizes 0.50 kilogram of NaCN per sack of ore material. This is a lot more than what is typically used in CIP circuits (0.50 to 1 kilogram of NaCN per tonne of rock). Prior to its full implementation, Mr. Isagani Rapsing, the pioneer of the *lugaw-lugaw* method, tested a range of cyanide concentration (0.15 kg, 0.20 kg, 0.25 kg, 0.30 kg, 0.35 kg and 0.50 kg) to distinguish the most effective amount in extracting the gold from a small amount of ore material. The amount of cyanide from the set-up that was observed to yield the highest gold recovery is then used as the baseline or minimum for the succeeding operations. However, if the ore material is suspected to be high grade, the amount of cyanide used per drum is increased to 0.75 kilograms. In the field, miners perceive that increasing the amount of cyanide will increase gold recovery.

The water-soluble (aurocyanide) formed is then adsorbed by the carbon. One kilogram of activated carbon is needed per 20 in rod mill. In instances when the ore material is suspected to be high- grade, the amount of carbon is doubled or tripled (2 to3 kilograms). A number of possible mechanisms have been suggested for the adsorption of aurocyanide onto the activated carbon. However, no consensus has been reached and all possible mechanisms can be simplified into one of three basic forms (Gray, 1999):

- The $Au(CN)^{2-}$ ion is adsorbed in the carbon without undergoing chemical change, and held by electrostatic or Van der Waals forces;
- The gold is decomposed from $Au(CN)^{2-}$ to Au(CN) and adsorbed as such;
- The aurocyanide is reduced to either gold metal or to a partially reduced state between gold (I) and gold (0).

Since both the dissolution and adsorption processes are condensed in one single step, the bulk of time consumed by the CID method is used in these fundamental stages. The time can be extended or increased based on the prerogative of the client or mining operator, the same way that the amounts of cyanide and activated carbon are increased when processing suspected high-grade ore materials.

(Step 4) Harvesting of Aurocyanide-laden activated carbon.

After an 8 to 10-hour dissolution and adsorption stage, the pulp was poured in a screen mesh to harvest the aurocyanide-loaded activated carbon. It was then burned in an improvised grill with coco shell charcoal for two hours.

Figure 11. Harvesting the gold. The aurocyanide-loaded activated carbon was harvested after several hours of dissolution and adsorption. It was then burned to liberate the metal concentrate from the carbon and other organic debris.

Figure 12. After burning with coco shell charcoal, the gold-loaded residue was captured using a mesh screen. Borax was then added.

The subsequent materials were separated using a screen mesh to capture the gold-loaded carbon residue. Borax was added in a 2:1 ratio prior to smelting.

(Step 5 and 6) Gold parting and Smelting. The gold-loaded carbon residue was smelted for two hours with borax at temperatures between 1,200°C to 1,400°C using a blowtorch. The resulting product (metal concentrate) is a combination of metals (i.e. gold, silver, etc.) weighing 1.9 grams.

Figure 13. Smelting of metal concentrate

To further refine the metal concentrate, nitric acid was applied to separate the gold from silver in a process called gold parting. Nitric acid, or aqua valens, is capable of dissolving the silver from finely-divided mixture of silver and gold, leaving the gold. If the acid is concentrated, the major product is NO_2 (nitrogen dioxide) which is released as red-brown fumes. A dilute version (25% HNO_3, 250 mL) of the acid was used, thus producing the major product HNO_2 (nitrous acid) which stays in the solution.

$$Ag + 2HNO_3 \Rightarrow AgNO_3 + NO_2 + H_2O$$
$$2\,Ag + 3HNO_3 \Rightarrow 2AgNO_3 + HNO_2 + H_2O$$

Figure 14. Heating with aqua valens and Smelting of gold concentrate

The gold concentrate was again heated with borax in a circular claypot for approximately 30 minutes. This particular smelting, or fusion process is the stage in which the impurities or contaminants from the gold concentrate are removed. This is achieved by heating the material in the presence of slag-forming fluxes at temperatures in excess of the melting point of all the components of the charge. Given the recovery of 1.4 g of gold from both mills, a gold grade of 12 g Au/tonne was retrieved.

ECONOMICS of the LUGAW-LUGAW METHOD

Small-scale miners who do not have mining facilities acquire the services of mining facility operators who provide the equipment, materials and manpower needed for processing the ore materials. These mining operators charge P800.00 per rodmill—which includes the lime, activated carbon, cyanide and borax used in the process. The mining operators charge extra in instances when the customer requests an increase of the amounts of the materials used and an extended milling time. The current price per gram of gold is Php 1,700.00

The two sacks of ore processed during the field activity produced 1.4 grams of gold, which amounts to Php2,380.00 The customer thus, takes home a net profit of Php 780.00.

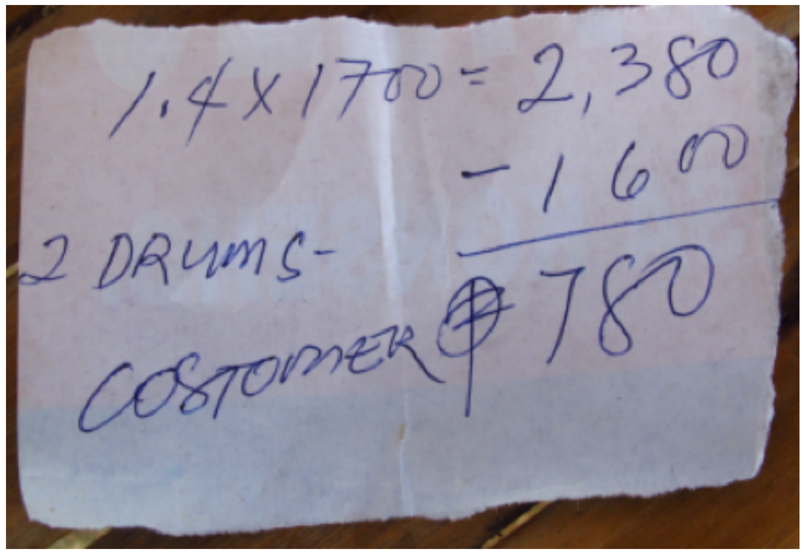

Figure 15. Net profit

However, the total amount of expenditures, based on the actual amount per unit of materials used, only amounts to Php 243.00 The difference is due to the fact that most of the materials, such as cyanide, can only be bought by bulk (per drum) and consequently used by the mining operator.

Table 2. Economics of the *lugaw-lugaw* method

EXPENDITURES	COSTS		PER UNIT
Materials / Equipment	**PHP**	**USD**	
Lime	5.00	0.12	Kilogram
Activated Carbon	128.00	3.09	Kilogram
Cyanide (sodium cyanide)	15.00	0.36	Kilogram
Borax	20.00	0.48	½ kilogram
Nitric acid	35.00	0.85	½ kilogram
Diesel	40.00	0.97	Liter
Acetylene	5.00	0.12	Liter
Operational Expenses			
Electricity	--not determined--		
Water	--not determined--		
Manpower	--depends on mining activity--		
TOTAL	**248.00**	**6.00**	**120 Kilograms of ore processed**

FIELD OBSERVATIONS

The liberation and extraction of gold using cyanidation processes greatly impacts the economics and the operations of the small-scale gold mining industry. These plant areas represent the primary fine gold recovery process and their technical and operational efficiencies will have a significant impact on the mining facility's overall output. When coming up with new innovations on methodologies and processes, the main objective is to develop a design which provides maximum technical and economic efficiency and which is robust to potential changes in ore throughput, mineralogical characteristics and head-grade. The variable that inherently affects the CID circuitry is the process control and accurate measurement. The equipment, quality and type would play a minor role, and many negative effects can be countered if process control and measurements are done right. However, there were several process issues that should be considered in the design of the circuitry, which also impacts how its primary objective is met.

Comparative Analysis of ASGM techniques

Three gold extraction methodologies are currently being used in small-scale mining operations in the Philippines. These are:

(1) *Benguet* method, which maximizes the laws of gravitation through improved sluicing techniques and use of indigenous and cheap materials, all in the goal of extracting gold without putting the environment at risk. This method allows for the extraction of macroscopic and microscopic gold particles from the ore without using toxic chemical substances in the process. Because of this, the *Benguet* method is viewed as an alternative to mercury amalgamation methods, as well as a break-out technique which allows women to partake in mining activities specifically in panning stages.

(2) Mercury amalgamation method, which employs the ability of mercury to bind to other metals, such as gold and silver, in the slurry. The use of mercury in small-scale mining has started in the late 1970s, and continuous to be a go-to process for small-scale miners looking for easy income. Though the process is perceived to be quick, concerns regarding the escalating prices of mercury has urged the miners to find alternative methods. Aside from this, mercury being a potent neurotoxin, has significant long-term effects to human health and the environment.

(3) *Lugaw-lugaw* method, a small-scale version of cyanidation processes employed by large-scale mining operations.

In the goal of providing a more in-depth analysis of the efficiency of the *lugaw-lugaw* method in extracting gold, a separate comparative demonstration of the 3 aforementioned processes was conducted in a mining facility in Masbate. The primary goal of the demonstration is to determine the process which will produce (1) the most volume of gold from the same set of ore material, and (2) the least amount of gold in the tailings. 180 kilograms of ore material were collected prior to the study. These were then mixed and divided into 3 rodmills-- with each rodmill representing one particular mining method. One kilogram of tailings materials were randomly collected after the run of each. The results of the comparative demonstration are summarized in the table:

Table 3. Results of the Comparative Demonstration between the three ASGM methods

PARAMETERS	MINING METHOD		
	***Benguet* method**	**Mercury amalgamation method**	**Cyanide-in-drum *(lugaw-lugaw)* method**
Amount of initial ore material (in kilograms)	60	60	60
Duration (in hours)	8	4	18
Amount of metal concentrate (in grams per tonne) prior to gold parting	10	16.67	10
Concentration of gold in tailings (in grams per tonne) [*,a]	60.11	11.92	5.36
Concentration of silver in tailings (in grams per tonne) [*,a]	14.8	5.72	6.08
Concentration of mercury in tailings (in ppm) [*,a]	----	0.64	----
Amount of mercury initially applied in the slurry (in grams)	----	2	----
Amount of mercury recovered from the slurry (in grams)	----	1.8	----

[*]results from fire assay conducted by Intertek Testing Services Philippines, Inc.
[a]Determination by 50g fire assay with AAS finish
[b]Determination by AAS following ore grade three acid digest (HNO3/ HClO4/ HCl) with volumetric finish
[c]Specialized acid digest/ cold vapor AAS

Aside from being the quickest method in extracting gold, mercury amalgamation has produced the highest amount of gold-containing metal concentrate among the 3 processes. However, to produce 0.6g of gold from 60kgs of original ore material, 2g of mercury was applied to the slurry. Of the 2g of mercury, only 1.8g were recovered, with pathways for mercury pollution stemming from the burning of amalgam, or dissolution in tailings. However, the ballooning costs of mercury traded in the black market contributes to the method's unsuitability as a mining method, not to mention major environmental and health costs attributed to mercury.

Furthermore, comparisons between mercury amalgamation and cyanidation processes stem on the characteristic sizes of the gold in the ore-- which further influence the result of the comparative study. To achieve a 90% recovery, cyanidation processes generally need fine grains of gold which measures from 0.2 mm or less. This is because a process dissolving the gold, such as cyanidation, requires fine particles to bring the gold into solution within a reasonable time. This is in contrast to amalgamation, where surface reactions result in gold grains being agglutinated rather than dissolved in Hg. As a result, amalgamation is only effective on gold grains with a particle size of 0.07–1.5 mm. Smaller grains may not get wetted by Hg due to the high surface tension and negative capillarity of Hg. If they eventually get dispersed in liquid Hg, they will not be brought so close to each other that they can adhere into an amalgam lump but can pass through the fabric, dispersed in the excess Hg pressed out (Hylander, et. al, 2006).

The Benguet method showed the same amount of metal concentrate as the lugaw-lugaw method produced, which can be considered as an impact of several limitations posed by the conditions in the field. Since the mining facility is originally for *lugaw-lugaw* and mercury method operations, the improvised sluicebox and launder did not provide the expected efficiency of the model ideally proposed by the alternative. Wooden sluiceboxes and launder have rough edges that inhibit the smooth flow velocity in the sluice, as well as the presence of innate trapping mechanisms that prevent some gold particles to be gathered in the dedicated launder. Increased panning time can also render the process more profitable since the amount of gold extracted through gravitation can be fully maximized.

Furthermore, the economics of the Benguet method makes it more advantageous for small-scale miners with minimal income since it capitalizes in indigenous materials and does not exploit the use of toxic substances in the extraction of gold. Comparing, for instance, to mercury amalgamation, in which "external costs" such as the (Concorde East/West, 2012):

(1) Additional cost required to keep mercury out of the environment, or at least to minimize the amount that reaches the environment. These include measures such as removing and collecting mercury from mining facility, contaminated soil and groundwater and sequestering the recovered mercury;

(2) Benefits for the people and the environment that would result from a phase out of mercury-use in mining. These includes reduced health costs, reduced environmental effects, additional jobs created, among others. These benefits are simply the "avoided costs" that would be accrued once a total shift is undertaken.

The application of the Benguet method to the mining community can therefore be facilitated if the correct infrastructure considerations are built and the miners are trained for implementation. Furthermore, some costs can be minimized if more sustainable measures are observed in the application, such as the use of rodmills powered by kinetic energy produced from water.

Table 4. Economics of the 3 ASGM methods

EXPENDITURES	**PRICE per UNIT**	**COSTS (per 60 kilograms of ore processed)**					
		Benguet method		**Mercury amalgamation method**		**Cyanide-in-drum (lugaw-lugaw) method**	
Materials / Equipment		**PHP**	**USD**	**PHP**	**USD**	**PHP**	**USD**
Lime	PHP 5.00 per kg	---	---	---	---	2.50	0.06
Activated Carbon	PHP 128.00 per kg	---	---	---	---	64.00	1.55
Cyanide (sodium cyanide)	PHP 15.00 per kg	---	---	---	---	7.50	0.18
Borax	PHP 40.00 per kg	15.00	0.48	10.00	0.24	10.00	0.24
Mercury	PHP10,000.00 per kg	---	---	20.00	0.48	---	---
Diesel	PHP40.00 per liter	20.00	0.49	20.00	0.49	40.00	0.97
Operational expenses							
Electricity	-- not determined --						
Water	-- not determined --						
Manpower	-- depends on mining activity						
TOTAL		35.00	0.97	50.00	1.21	124.00	3.00

Fire Assay for Gold (Activation Laboratories Ltd.)

Fire assaying is considered to be the industry standard when it comes to obtaining analytical gold data from high grade ores from all sample types, including drill core, soil and chip samples. The process can be summarized in 3 steps:

1. Fusion

The pulverized sample is first weighed and mixed with a fluxing agent. Aside from facilitating the melting process, the flux helps in fusing the sample at a reasonable temperature by promoting the separation of the gangue material from the precious metals. Lead or nickel is added as a collector is also added in the sample. The sample is then heated in a furnace where it fuses and separates from the collector material 'button', which contains the precious minerals.

2. Precious metal extraction

When the button and the gangue have already separated, the precious metals are extracted from the collector through a process called cupellation. Once cooled, the button is separated from the slag and cupelled. Two collectors can be used:

- Lead. Lead oxidizes and is absorbed into the cupel leaving a precious metal bead. The bead is then dissolved in aqua regia for analysis.
- Nickel. The button is crushed and dissolved in hydrochloric acid. The residue is then filtered to remove extraneous material, leaving the precious metal residue on the filter.

3. Analysis and Detection by Flame Atomic Absorption

The sample is dissolved in aqua regia and then aspirated in an acetylene flame. A beam of light at a wavelength matching that of gold is passed through the flame. The concentration of the gold in the solution is measured by the amount of light that it absorbs in the solution. Standard solutions are used as a basis of comparison in determining the gold concentration in the sample.

Technical Observations

An assay of the tailings produced after the *lugaw-lugaw* method showed that there is still a significant amount of gold concentration that was not adsorbed and extracted from the process. The assumption that CID can be liken as a "mill-to-waste" method was not put through because of some gaps in addressing the parameters that affect its performance. Some of these were observed during the documentation work:

1. **Grind size and gold particle size.** Maximum economic liberation of gold can only be achieved if the right grind size is attained. This can be done if the equipment (i.e. rod mill) operates in its optimum speed, functions in the ideal number of rotations per minute (rpm), at the same time have more power to run longer to get the right grind. In the documentation activity, the time of milling was extended because the miners felt that the initial time estimate was not sufficient enough to achieve the desired consistency of the pulp needed to liberate the gold. However, it must be noted that pulp consistency is a poor representation of the grind size achieved and must be computed and studied further. Adding to this, too large gold particles may not be dissolved in the solution due to the process conditions in the field. Additionally, the rate of agitation can play a minor role and affect the mechanisms of gold leaching, and cases were agitation at low rates was applied to save power has resulted in low leach recoveries.

2. **pH.** Lime is added to modify the pH and to immediately create an alkaline aqueous environment so that minimum cyanide is lost by conversion to HCN gas. However, increase in pH due to lime addition also influences and slows down the cyanide leach kinetics. The pH of the slurry dictates the rate and efficiency of adsorption of the aurocyanide complex in the slurry. To acquire a pH of 10.5, miners should look on the specific properties of the ore material and the total volume of the sample. Since an increase in pH creates competition between hydroxide ions

and aurocyanide for the free binding sites in the carbon, the pH conditions of the slurry must be regularly maintained and monitored starting from the loading stages. In some very rare cases, ores have a naturally alkaline pH of 9.5 or higher, thus no lime is needed at all.

3. Cyanide consumption. There are many components in a typical ore that will consume cyanide by side reactions. In addition, cyanide is also lost by hydrolysis. In order to achieve effective leaching, cyanide concentration must be maintained at a minimum level. The actual rate of cyanide consumption for a specific ore will vary depending on its characteristics. Doubling the amount of cyanide given the small volume of ore material being processed does not necessarily translate to more efficient gold dissolution and adsorption.

4. Oxygen demand. Oxygen is a crucial reagent for leaching. Even though the water and the ambient air inside the drum serve as sources of oxygen, the pulp may contain organic and inorganic components that consume oxygen. The presence of such components reduces the overall level of dissolved oxygen in the pulp, thus reducing leach kinetics and leach efficiency. This is the reason why air is often supplied as a reagent in CIP/CIL circuits, a parameter that is not duly addressed by the CID method.. The CID method needs to measure the dissolve O_2 over the entire course of the leach. While low O_2 could play a big role in the cyanidation process, it is a parameter that can be easily fixed.

5. Residence time and carbon attrition. Depending on whether the ore is a low-grade dump material, or a high-grade material, residence time is an important factor to achieve favorable and acceptable leach recoveries. In CIP/CIL circuits, residence times may vary from 12 to 48 hours. In the case of the *lugaw-lugaw* method, since the gold dissolution and carbon adsorption stages were combined and condensed, the residence time is reduced to 8 hours. This reduction in residence time may not be sufficient for either the formation of the aurocyanide complex or its subsequent adsorption to the carbon. Condensing the two stages does not necessarily inhibit leach kinetics, however, it can result to carbon attrition. When the carbon is freely exposed in the leach more pre-grobbing will occur as a result of small carbon particles taking the gold through the screen at the end of the leach.

6. Pulp density. Pulp density affects viscosity considerably, which has an impact on gold leaching. It has been found that pulp densities which are too high, as well as those which are too low can affect gold leaching performance in a negative manner. Overly dense pulps hinder mass transfer whilst dilute pulps result in a loss of ore leaching residence time as well as high reagent addition rates. Since the type of ore processed requires a higher volume of water compared to other ore types, care must be taken in ensuring that the appropriate pulp density is achieved through addition or reduction of water. It must be noted that a proportion of 30 to 40% solids by volume should be achieved, not mass.

7. Mercury interference. The mining facility were the procedure was documented was formerly a facility for the mercury-gold amalgamation process. Former rod mills that were used for the mercury-based process inherently retain some parts of the mercury volume because of mercury's ability to bind to metallic objects such as the drum of the mill. This suggest that the rod mills may be contaminated with a significant amount of mercury that is capable of competing with gold and other metals such as silver and copper by forming a mercury-cyano complex with the free cyanide ions in the solution (Coles & Cochrane, 2006). This can be a huge problem for facilities that had just made the transition from mercury method to cyanidation. Though it may have a minimal impact on the effectiveness of the lugaw-lugaw method in the field, the practice of processing mercury amalgam tailings must be avoided since cyanide lends mercury enhanced mobility to contaminate groundwater and ultimately drinking water supplies where removal to an acceptable level could only be achieved at an exorbitant cost.

Determining the impact of the aforementioned parameters on a particular pulp requires that extensive experimental work in a broad range of representative sample be done. Some parameters, such as pH, grind size, among others depend on the type of ore or ore material that will be processed. The level of scatter and noise is inherent with any type of metallurgical work, and if CID is set to be the response to the need to shift from mercury-based processing of a small volume of ore, the potential of the process must be maximized and regulated through exploring the process control measures.

>>IMPLICATIONS to the COMMUNITY

Background

The Municipality of Aroroy is a first class municipality in the province of Masbate, with a total number of 10,736 households distributed to 13 barangays. As of 2000, there are 58,000 people residing in the municipality. According to the local government unit officials, the primary sources of livelihood of the residents are: (1) agriculture (farming and fishing) and (2) mining (large-scale and small-scale). Mining activities in the community are concentrated in 8 *barangays*.

MERCURY and CYANIDE USE

Small-scale mining operations which started in the early 1970s used crude hand-driven crushers and grinders to extract the gold. These operations expanded to 8 *barangays: Tinago, Buyuan, Talaban, Luy-a, Balete, Concepcion, Pangli, Pinanaan, Manamok and Ambulong*. Miner participants of the focus group discussion organized by BAN Toxics estimated that at least 75% of the residents from these barangays engage in small-scale mining activities—some of whom are young adults and teenagers (15 to 21 years old).

Mercury-use in small-scale gold mining was first introduced in 1982 by *Benguet* miners who migrated in the area. *Benguet* miners were the first individuals who discovered the presence of gold in the region, as well as pioneered the use of different gold extraction techniques adopted by the local miners. Later, in 1988, the gold cyanidation process was introduced by a certain Mr. Corpuz. Former employees of a large-scale mining corporation based in Mt. Diwalwal, Compostela Valley also invested in building small-scale CIP circuits in the municipality in 1995. The technique became popular since then, when miners realized the need to maximize the method's ability to extract microscopic or fine-sized gold.

Since the ore materials found in the region are composed of a combination of macroscopic and microscopic gold particles, the ore materials first undergo the mercury amalgamation process to capture gold with particle sizes from 0.07 to 1.5 mm. The subsequent tailings containing the remaining fine gold undergo the cyanidation process. The method incorporating the use of mercury is favored due to the fact that it is considered by the local miners a fast and easy process, thus, the effort and capital expended in the mining activity are returned immediately. With the growing familiarization with the cyanidation process as a method of extracting fine gold, cyanide is now commonly used for its efficiency in capturing the gold and is also used to ensure that no gold particle is wasted.

Table 5. Comparison between Mercury and Cyanide use in Small-scale Gold Mining (Focus Group Discussion outputs)

METHOD	Reason for Use	Disadvantages	Price	Average Estimate Consumption
MERCURY	✔ Fast and easy ✔ Only small volume is needed for processing	• Mercury is lost during smelting and is not reused • Puts the miner's health and the environment at risk	Php 8,000.00 – Php 10,000.00 /kilogram	2 grams of Hg: 1 gram of Au A 100 gram amalgam contains 30- 40% of gold and 60- 70% of mercury
CYANIDE	✔ More efficient in getting gold ✔ Cyanide tailings can be detoxified to reduce impacts	• Large volume is needed per cycle • Highly toxic	Php 14,000.00 per drum (50 kilograms minimum)	--no data available--

ISSUES OF CONCERN

The advent of new technologies and methods in the small-scale gold mining industry, such as CID, raises several challenges that must be addressed by the local government and community. These are:

1. Lack of government oversight or regulation of the small-scale mining sector.

Majority of small-scale mining operations in the Philippines operate without a permit or is sanctioned by law. As can be seen in this study, small-scale miners are dealing with not only toxic chemicals such as cyanide, but also in resource extraction and waste generation as well. The activities and processes used in the sector have a great impact in both the immediate and downstream communities. For the most part government has been absent in the lives of the miners, as the study has encountered. This is unfortunate as there can be a lot to gain with government support and monitoring of the sector. Technical guidance, safety inspections, community development are some of the major gains the small-scale mining sector can benefit from with strong government involvement in the sector. With the continued absence of the government participation and monitoring ultimately affects not just the miners but the small-scale mining community and communities dependent on the sector for livelihood.

2. Non-compliance with DENR Chemical Control Order No. 97-39 (CCO) dealing with cyanide and cyanide compounds.

CCO 97-39 was issued to control the use of cyanide and its compounds, and their dispersion into the environment to avoid adverse health and environmental impacts.

The CCO applies to the importation, manufacture, processing, use and distribution of cyanide and cyanide compounds and addresses the areas of treatment, storage and disposal of cyanide bearing or cyanide-contaminated wastes in the Philippines. Moreover, the CCO has permit requirements, records and reporting, limited use and disposal, as well as handling and transport requirements. Currently, two cyanide distributors are complying with CCO permits in the municipality, however, the miners cited that there are peddlers who sell these toxic chemicals illegally. From the extent of

3. Absence of a municipality mining waste management plant.

Monitoring of wastes from mining operations are made by ensuring that these operations continuously follow the mandatory requirements set by the Department of Environment and Natural Resources- Environmental Management Bureau (DENR-EMB) on waste water management. The Municipal Environment and Natural Resources Office (MENRO) conducts annual monitoring and evaluation, which includes checking and monitoring for compliance and maintenance by ensuring that the tailings ponds have good dam design/ engineering and stability. These requirements provide mitigation responses to groundwater contamination and pollution. Tailings from mercury-based gold extraction operations, particularly whole-ore amalgamation processing, are hauled in sacks and sent to cyanide plants for processing.

Previously, the local officials planned to create a central processing area or *minahang bayan*, where all tailings from the whole community will be brought and processed through gold cyanidation. This plan, however, did not push through because of the opposition of operators who believe that the added cost of transporting the tailings, as well as losing control over their tailings, will eat a huge chunk of the net profit.

4. Absence of emergency response and precautionary guidelines.

The municipality does not have a comprehensive general emergency response plan and precautionary guidelines in place, not only for CID but for mining operations in general. Some mining operations only have a first aid kit in cases of suffocation or difficulty in breathing. To prevent accidents during tunnelling, operations are reduced during the rainy seasons, which lead to increase activities concerning the processing of tailings stored initially. Each plant owner also designs their tailings ponds in a way that anticipates the volume of waste water produced in processing. This results to the construction of larger dikes and dams to accommodate increase in production.

5. Lack of capacity of healthcare workers to manage toxic exposure.

When asked about health impacts of cyanide and mercury, the majority of the health workers exhibited a lack of capacity in diagnosing, treating and managing patients exposed to toxic chemicals. Awareness on the effects of cyanide and mercury on human health were not discussed, since they haven't encountered any incident of toxic poisoning in the community. The healthcare workers, however, have observed an increase in miscarriages in several barangays involved in small-scale mining, though they weren't sure if it is directly linked to toxic chemical exposure. The health workers admitted their lack of skills in diagnosing either mercury or cyanide poisoning. While there are no cases of poisoning involving miners in the previous year, there was an incidence of suicide through cyanide dosing.

6. Access to information / technical expertise.

As elaborated on in this report, there are areas of improvement for the CID process. What is missing here, is the access of miners or operators such as Mr. Rapsing to technical data or expertise on how to improve his system. The local government unit of Masbate should have the technical capacity to help the miners in this regard, but it currently does not. This is the challenge faced by miners such as Mr. Rapsing on how to find reliable and accessible information that can elevate his technical capacity to get better returns in his investment, improve safety and better protect the environment.

>>CONCLUSIONS and RECOMMENDATIONS

Conclusions:

1. The CID method as documented is currently flawed. One of the glaring gaps in the process is the need for proper measurement, e.g. of the pH level, grind size, etc. and lack of process control or management. The miners employing the CID method are merely "eye-balling" or estimating critical measurements that can greatly aid in improving recovery, cost, and safety. The CID process needs to mature further and go through further testing and refinement before it can be fully applicable in ASGM.

2. Lack of access to credible technical information and expertise. There is a lot of creativity and inventiveness in the mining area as seen by the development of the CID method. However, what stifles the creativeness is the lack of guidance or access to good technical information.

3. Absence of government participation and monitoring of the sector. See discussion above.

4. Mining methodologies and processes are dynamic. Methods that are commonly used in large-scale mining operations can be adopted by the small-scale mining industry to forge the need to process gold-bearing ores effectively, or to maximize the output from tailings that are already processed through other methods. This shift is driven by the need to supplement the economic needs of the miners and to decrease the capital and operational expenses of such endeavors.

5. The environmental and societal implications of such mining technologies are not commonly prioritized, or even considered. Not only does the increase of reagents use, such as cyanide, affect the efficacy of the method, but it also increases the risk of exposure of the workers and the environment to the harmful and toxic effects of such chemical substances. Mercury risks are chronic and are nearly impossible to manage because of the element's persistence in the environment and ability to bioaccumulate. Cyanide on the other hand, though easily decomposes, must be handled properly to avoid the risk of acute intoxication. In either cases, knowledge on how these impact the environment and human health must be disseminated.

6. The application of large-scale methodologies to small-scale ones cannot be simply done by minimizing the initial input and doubling reagents and time duration. Metallurgical work has an inherent level of scatter, and if parameters affecting the circuitry are not properly addressed, the mining trend will not be helpful at all in achieving its primary objective, that is to retrieve the gold from fresh ores or from tailings, and will be considered as a methodology that is only good in theory but poor in performance. Process control and metallurgical investigations need to be conducted prior to implementation of any process, large or small. Understanding and application of sampling protocol will ensure that these investigations can produce confident results.

7. The community is not prepared to manage the shift in technology, particularly technical competency. Information on mining methodologies travel fast and are easily adopted and improved, however, the local government and other sectors fail to cope with the uprise of issues that come with new methodologies and processes. Implementation and enforcement of current policies are delegated to a small portion of the workforce of the local government, and some local government units do not have the capacities to monitor and evaluate the impacts of the industry at the grassroots level. For instance, the healthcare units are not equipped with the basic skills and information needed to manage negative health impacts brought about by toxic chemical substance, may it be mercury or cyanide. The role of healthcare workers are crucial in the community level, since they are also expected to disseminate information on aspects that impact the health of the members of the community. While the miners themselves are left unaware with the basic precautionary procedures relating to their occupational safety and health. Given that small-scale gold mining is one of the main sources of living of the majority of the people, a commitment by all stakeholders to answering the concerns arising from the industry is needed.

Recommendations:

1. Process control and metallurgical investigations need to be conducted prior to implementation of any process, large or small.

2. While the CID method appears to be a viable solution to mercury use in ASM, any method using cyanide will not be socially or economically successful if poor measuring and/or poor process management prevails. As shown by the poor results of the CID process outlined in this study, increasing the technical capacity of cyanide ASM users through training and outreach by experts or access to reliable technical information to ASM will confidently increase recovery allowing cyanide-only methods such as CID to greatly outperform mercury. Furthermore, indigenous methods such as the Benguet method can better help miners to earn income, at the same time eliminating risks to human health and the environment.

   a. For artisanal and small-scale miners without facilities or capital, utilizing the Benguet method and abandoning mercury amalgamation is highly recommended.

   b. For small-scale miners who have facilities and capital and are already invested in cyanidation, a two-step process can be undertaken. First, eliminate whole-ore amalgamation or any form of mercury amalgamation before cyanidation, and second, utilize effective gravity concentration like the Benguet method, before applying cyanide. Proper measurement of the cyanide and grind size as well as strict process management should be achieved to optimize results, and to finally neutralize the cyanide while in the drum before its release to the environment.

   c. Awareness raising and capacity-building strategies must be developed in order to alleviate any negative impact to the miners and the community to assess the perception and openness of the people in the community in welcoming such new practices. Behaviours and perspectives that put environmental and economic benefits at opposite ends of the equilibrium greatly hinder the success of any methodology.

   d. Meaningful government engagement is needed, not just taxing the gold or generating revenue, but at the level of community development, providing technical expertise, monitoring, and providing basic services to the community. The small-scale mining sector is one of the main economic drivers in the countryside, and its high time the government pays attention to the needs of the sector and bring it in within the scope of a legal and protected industry.

>>BIBLIOGRAPHY

20 Mule Team Borax. (2012). Borax Decahydrate. Retrieved December 15, 2012, from 20 Mule Team Borax: www.borax.com/product/borax-decahydrate.aspx

Activation Laboratories Ltd. Quality Analysis, Innovative Technologues. Fire Assay Analysis. Ancaster, Ontario. Retrieved July 16, 2013 http://www.actlabs.com/page.aspx?menu=72&app=240&cat1=619&tp=2..

Concorde East/West. (2012, March 5). The Real Cost of Dental Mercury. Retrieved July 15, 2013 from Mercury Policy Project mercurypolicy.org/.../real_cost_of_dental_mercury_april_2012-final.pdf

Deithorn, R., & Mazzoni, A. (n.d.). The Story of Activated Carbon. Retrieved December 15, 2012, from TIGG Corporation: www.tigg.com/what-is-activated-carbon.html

Ferrari, L., Kaufmann, J., Winnefeld, F., & Plank, J. (2010). Interaction of Cement Model Systems with Superplasticizers investigated by atomic force microscopy, zeta potential and adsorption measurements. Journal of Colloid Interface Science, 15-24.

Gray, D. E. (1999). A Quantitative Study into Carbon-in-Pulp Adsorption Operations. Cape Technikon.

Ground Truth Trekking. (2012, August 28). Gold Cyanidation. Retrieved December 15, 2012, from Ground Truth Trekking: www.groundtruthtrekking.org/Issues/MetalsMining/GoldCyanidation.html

Hylander, L. D., Plath, D., Miranda, C., Lucke, S., Ohlander, J., & Rivera, A. Comparison of different Gold recovery methods with regard to Pollution Control and Efficiency. Retrieved July 4, 2013 from UNEP: http://www.unep.org/hazardoussubstances/Portals/9/Mercury/Documents/PartneshipsAreas/HylanderEtal_CLEAN-07.pdf

International Cyanide Management Code. (n.d.). Cyanide Chemistry. Retrieved December 15, 2012, from International Cyanide Management Code for the Gold Mining Industry: www.cyanidecode.org/cyanide-facts/cyanide-chemistry

International Cyanide Management Code. (n.d.). Use in Mining. Retrieved December 15, 2012, from International Cyanide Management Code for the Gold Mining Industry: www.cyanidecode.org/cyanide-facts/use-mining

Rubo, A., Kellens, R. R., Steier, N., & Hasenpusch, W. (2006). Ullmann's Encyclopedia of Industrial Chemistry. Weinheim: Wiley-VCH.

Stange, W. (1999). The Process Design of Gold Leaching and Carbon-in-Pulp Circuits. The Journal of the South African Institute of Mining and Metallurgy, 13-26.

The Shark Group. (2000, June 8). Common Mining Terms. Retrieved December 15, 2012, from Mining the Motherlode: www.wells.entirety.ca/terms.htm

Veiga, M. D., Metcalf, S. M., F, B. R., Klein, B., Davis, G., Siegel, S., et al. (2006). Manual for Training Artisanal and Small-Scale Gold Miners. Vienna: United Nations Industrial Development Organization.

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