Introduction to Cyanide Gold Mining

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ORE CHARACTERIZATION

- Gold occurs in a variety of geologic environments. Estimates of average abundance in the Earth's crust are on the order of 0.003 to 0.004 parts per million (ppm) (U.S. DOI, Geological Survey 1973). Deposits considered to be economically recoverable at current market prices may contain as little as 0.69 to 1.37 ppm [0.02 to 0.04 troy ounces of gold per ton of rock (oz/t)], depending on the mining method, total reserves, and the geologic setting of the deposit.

- **Types of Gold Ore Deposits**: Sediment-Hosted Disseminated Gold, Volcanic-Hosted Epithermal Deposits, Porphyry Copper-Related Deposits, Greenstone Gold Quartz Vein Deposits
Basic Process Steps: Newmont

• **1. Mining**: To define the ore from the waste rock, samples are taken at set intervals along surveyed lines within the pit. These samples are assayed. Assay results are used to mark out areas of ore and waste rock, which are mined separately. Some of the harder areas require blasting to loosen the rock prior to excavation by hydraulic diggers. Dump trucks haul the rock to the primary crushers.

• **2. Crushing**
  The primary crushers and a jaw crusher - located at the mine site, receive ore and waste at separate times. They break the larger rocks down to a size suitable for transport on the conveyor.

• **3. Transport**
  Most mines transport ore and waste using large trucks. Some mines transport the ore and waste rock to the mill and waste disposal area via belted conveyor.

• **4. Grinding and Sizing**
  Ore is stockpiled at the mill before being fed into a semiautogenous grinding (SAG) mill with lime, water and steel balls. The larger particles from this mill are returned to the SAG mill for more grinding. The finer particles receive more grinding in a ball mill.
Basic Flow Sheet Part 2

• 5. Leaching & Adsorption
A slurry of ground ore, water and a weak cyanide solution is fed into large steel leach tanks where the gold and silver are dissolved. Following this leaching process the slurry passes through adsorption tanks containing carbon granules which adsorb the gold and silver. This process removes >90% of the gold and >70% of the silver.

• 6. Elution & Electrowinning
The loaded carbon is fed into an elution column where the bullion is washed off. The barren carbon is recycled. The wash solution—pregnant electrolyte—is passed through electrowinning cells where gold & silver is won onto stainless steel cathodes.

• 7. Bullion Production
The loaded cathodes are rinsed to yield a gold and silver bearing sludge which is dried, mixed with fluxes and put into the furnace. After several hours the molten material is poured into a cascade of moulds producing bars of doré bullion.

• 8. Water Treatment
Some water from dewatering the mine, from the embankment underdrains and decantation from the tailings pond is recycled for use in the grinding circuit. Excess water is pumped to the Water Treatment Plant and treated to the required standards before discharge into the river.

• 9. Tailings Disposal
Waste rock from the mine is used to build the embankment structures. The embankment retains the tailings slurry in a pond where solids settle.
CIL (Carbon In Leach)

• To leach the gold out of the ore and into solution, cyanide, and oxygen must be added to the slurry. Lime is added to the grinding circuit to modify the pH of the slurry to prevent the formation of deadly hydrogen cyanide gas. Cyanide is added in liquid form to the tanks. Lead nitrate is added to the leach circuit and has the effect of accelerating the gold dissolution rate. Oxygen is added in pure form, injected down the agitator shafts.

• The dissolved gold in solution is adsorbed onto activated carbon. When the carbon is loaded with enough gold it is removed from the circuit and sent to elution where the adsorption process is reversed and the gold is stripped off the carbon back into solution, electrowon and smelted into bars.

• The remaining ‘barren’ slurry reports to the tails thickener and is pumped to the tails dam.

• The CIL circuit consists of two separate trains of tanks, with 6-8 tanks in each train. In conventional CIL circuits, leaching takes place in the presence of carbon and therefore leaching and adsorption occur simultaneously.
CIL Tanks
Carbon Adsorption

• After the leaching process is complete, the soluble gold must be concentrated and separated from the process slurry. The method of recovery of gold from the process slurry is by carbon adsorption.

• Adsorption is a term used to describe the attraction of a mineral compound to the surface of another material.

• Activated carbon is used to adsorb the gold out of solution. Because the cyanide ion forms very strong complexes with gold, it is the gold cyanide complex that is loaded onto the carbon rather than being deposited as metallic gold.

• Gold loaded onto the carbon is then stripped using either acid or cyanide and that solution is sent to electrowinning
Gold Furnaces and Refinery

• After gold is washed off electrowin cathodes, it is placed in trays and dried in a furnace. This heat treatment may cause mercury emissions.

• After drying, the gold ore is placed into a gold refinery furnace (retort) where the ore is melted into dore gold bars. The refinery may also be a source of mercury emissions.
Wastes Generated at Gold Mines

- **Waste Rock**: these materials are deposited in waste rock piles or dumps. At surface mines, 71 percent of all material handled is discarded as waste. Constituents found in gold ores may include mercury, arsenic, bismuth, antimony, and thallium. These may occur as oxides, carbonates, and sulfides with varying degrees of solubility.

- **Spent Ore from Tank Leaching (Tailings)**: Tank leaching, both CIP and CIL circuits, generate spent ore by leaching the gold values from finely ground ore. The spent ore exits the leach circuit as a slurry composed of gangue and process water bearing cyanide and cyanide-metal complexes. The tailings may be treated to neutralize cyanide prior to disposal. The slurry is typically disposed of in a tailings impoundment with some of the free liquid component being recirculated.
Wastes Generated at Gold Mines (continued)

- **Cyanide Solution**: During operation, most of the barren cyanide solution is recycled to leaching activities. However, the buildup of metal impurities may interfere with the dissolution and precipitation of gold and, therefore, require a portion of the solution volume to be bled off and disposed of.

- **Wastes From Carbon Regeneration**: generally involves an acid wash before or after extraction of the gold-cyanide complex, followed by reactivation in a kiln. Could be a source of mercury emissions.
Anticipated Environmental Impacts

• **Mine Impacted Waters**: Used to be called Acid mine Drainage or Acid Rock Drainage. See GARD Guide. Metals mobilize under neutral, acid or alkaline conditions.

• **Mine Dewatering**: Drawdown on GW and Streams

• **Release of cyanide process or spent solutions**

• **Detoxification of Cyanide**: Detoxification of cyanide using hydrogen peroxide is applicable to spent heaps, tailings, and solution ponds and tanks. The INCO process uses SO2 and air, which is dispersed in the effluent using a well agitated vessel. Acid produced in the oxidation reaction is neutralized with lime at a controlled pH of between 8 and 10
NPL Mine Sites in South Carolina: Barite Hill/Nevada Goldfields

- **Site Summary Profile**
  - EPA ID: SCN000407714
  - Location: McCormick, McCormick County, SC
  - Lat/Long: 33.8711, -082.2972
  - Congressional District: 03
  - NPL Status: Proposed: 09/03/08; Final: 04/09/09
  - Affected Media: Ground water, Soil
  - Cleanup Status: Early Action Initiated/Completed and Study Underway - Physical cleanup activities have started.
  - Site Reuse/Redevelopment: Potential for Commercial/Light Industrial
  - Site Manager: Candice Jackson (jackson.candice@epa.gov)

- **Site Background**
  - The 795-acre Barite Hill/Nevada Goldfields site is located approximately three miles south of McCormick, in McCormick County, South Carolina. The site was actively mined for gold and silver from 1991 to 1995. Operations included the heap leaching of gold from ore, using a weak cyanide solution. Nevada Goldfields used seven processing ponds and one sediment pond to process the “pregnant” solution that contained the gold. After the closure of the mine, the approximate 10-acre Main Pit began to fill with water. At its highest, the pit contained approximately 60 million gallons of water with an average pH of 2.0 and high dissolved metals content. Nevada Goldfields pursued site reclamation activities from 1995 until filing for bankruptcy in 1999. The property was then relinquished to the South Carolina Department of Health and Environmental Control.

- **Threats and Contaminants**
  - Former site operations resulted in the contamination of the Main Pit, ponds, sediment, surface water, and soil with arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, zinc, and cyanide. Metals were also detected in surface water and sediments of Hawe Creek and its tributaries. Because Hawe Creek is a fishery, people could have been exposed by eating contaminated fish. Additionally, Hawe Creek empties into a drinking water reservoir. There was also a risk that water in the Acid Pit will overflow and acid/metals-laden water will enter the reservoir.

- **Site Cleanup Plan**
  - Several interim remedial actions for this site have been completed and monitoring of these efforts is underway. A final remedy for the site will be selected based on sampling and monitoring results conducted as part of the Remedial Investigation (RI). RI activities began at the site February 2011.

- **Cleanup Progress**
  - EPA conducted a Removal Site Evaluation in 2007. Emergency response activities included demolition of a furnace building and on-site neutralization of over 2,000 lbs of acids and bases. A subsequent removal action commenced on October 15, 2007 and included a Bureau of Reclamation-designed cap for the 250,000 cubic yards of acid-producing waste rock adjacent to the Acid Pit. On February 4, 2008, efforts to neutralize the Acid Pit commenced using carbide lime combined with a patented carbon loading treatment.
  - Grading, capping of the north and south waste rock piles, and construction of a spillway were completed by October 2008. An advanced monitoring system to monitor the waste rock cap and the Acid Pit was installed in 2009.
NPL Sites In South Carolina: Brewer Gold Mine

• Site Summary Profile
  EPA ID: SCD987577913
  Location: Jefferson, Chesterfield County, South Carolina
  Lat/Long: 34.652190, -80.411470
  Congressional District: 05
  Affected Media: Ground water, Surface Water
  Cleanup Status: Physical cleanup activities are underway
  Site Reuse/Redevelopment: None
  Site Manager: Loften Carr (carr.loften@epa.gov)

• Site Background
  The 1,000-acre Brewer Gold Mine site is located on the western border of Chesterfield County, in a rural area approximately 1-mile west of Jefferson, South Carolina. The disturbed area that supported mining activities covers 230 acres in the eastern portion of the larger property.
  The Brewer Gold Mine operated from 1828 - 1995. From 1987 through 1995, the Brewer Gold Company mined over 12,000,000 tons of ore and waste rock from several open pits. In 1990, following large rainstorms, a dam broke and allowed over 10 million gallons of cyanide solution to escape and flow into Little Fork Creek. The dam and plastic-lined pond were repaired and the company resumed mining in 1991. The State required Brewer to close and reclaim the mine. Brewer placed all the rock it had mined, including both waste rock and spent ore, back into the open pits, along with the dismantled plant and the plastic liners that had been under the heaps. They then had to cap the filled Brewer and B-6 pits and re-vegetate the entire site. While the company was completing its closure and reclamation activities, acid rock drainage began to emerge from several seeps a few hundred feet from Little Fork Creek. Brewer Gold constructed a plant to treat the contaminated water and received a permit from South Carolina Department of Health and Environmental Control (SCDHEC) that allowed the treated water to be discharged to Little Fork Creek. Brewer operated the treatment plant from 1995 -1999.

• Site Cleanup Plan
  An interim Record of Decision (ROD) for the site was issued in 2005. The ROD detailed interim cleanup activities for the site, including:
  – Collecting contaminated seepage from several springs downstream of the backfilled pits and injecting it into the B-6 Pit.
  – Pumping contaminated water out of the B-6 Pit and from the sediment pond and storing it in a lined storage pond.
  – Treating all contaminated water with lime in an on-site wastewater treatment plant and discharging the treated water into the Northwest Trend Pit.
  – Periodically removing sludge from the Northwest Trend Pit, drying the sludge, and storing it in on-site piles.
  – Evaluating the potential for contaminants to be released from sludge while it is stored. If it is determined that contaminants could be released, developing and implementing a sludge management plan pending development of a final cleanup plan.
  – Monitoring water quality of the effluent discharge and surface water in the Little Fork Creek.

• Cleanup Progress
  • In August 2005, EPA completed a focused Remedial Investigation/Feasibility Study (RI/FS) that recommended continued treatment of the contaminated water in the existing wastewater treatment plant as an interim action.
  • Interim cleanup activities began at the site in December 2006.
  • EPA completed a sitewide RI in 2010 and is currently conducting an FS to identify and evaluate a cleanup approach for the site.