Three-Phase Mining Effluent Treatment Plant To Meet Stringent Standards

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Abstract High-rate ballasted flocculation technology, cyanide oxidation and carbon adsorption make up an advanced, three-phase cyanide and metals removal system for Marlin Mine. The new plant is designed to meet compliance with the International Cyanide Code and other highly stringent standards. The new wastewater treatment system was installed to allow treatment and subsequent discharge of the tailings water to the environment. This paper will describe the treatment processes and provide the treatment results.

Key Words Cyanide, cyanide oxidation, sand-ballasted flocculation, clarification, disc filter, metals removal, mine water, tailings treatment

Project Description

An advanced cyanide and metals removal system was completed in January 2009 at Marlin Mine, located in Guatemala 48 kilometers southwest of the city of Huehuetenango, approximately 300 kilometers northwest of Guatemala City. The Marlin project is a combination of open pit and underground mining with a conventional milling operation that began commercial production in December 2005. The mine is owned by Montana Explorada de Guatemala, S.A., a wholly-owned subsidiary of Goldcorp Inc. The mill is designed to treat a minimal 1.82 million tons of ore per year. Marlin achieved 227,200 ounces of gold and more than 2.8 million ounces of silver in 2007, its second full year of production.

Operations include a cyanide milling facility where ore is subjected to cyanide leach solutions in the Merrill-Crowe recovery process. The solution is separated from the ore and the gold is cemented by adding zinc dust, which precipitates the metal. The tailings and water generated from this process are treated with an air cyanide removal technology prior to discharge to the mine's tailings impoundment. This process utilizes SO_2 and air with pH control to treat the water prior to discharge to the mine's tailings impoundment. This process destroys the metal cyanide complexes present in the gold mining effluent. The impoundment currently has a capacity of 4 million cubic meters of tailings and is expected to expand to nearly 20 million cubic meters by the end of the mine's life.

Because the mine will likely need to discharge water from its tailings impoundment at some point in the future, Marlin built the new water treatment plant exclusively for that purpose. Goldcorp has an excellent reputation and regard for environmental protection. The company has taken extra precautions beyond what is legally required by self-imposing additional stringent standards at its Marlin Mine project. To ensure this greater level of protection, Goldcorp requires compliance with the International Cyanide Code and other more stringent requirements, including World Bank standards. For example, final effluent limits for the new water treatment plant include 0.5 ppm WAD (weak acid dissociable) cyanide, 0.1 ppm free cyanide and 1.0 ppm total cyanide. There is also an extremely low level discharge limit for metals, including mercury (Hg) of 0.002 mg/L

Montana Explorada de Guatemala, S.A. awarded an engineering, procurement and construction management contract for the cyanide oxidation and metals removal plant. The new system is capable of treating water from Marlin's tailings impoundment at a rate of 2,200 gallons per minute.

The treatment plant has three specific phases of treatment – cyanide oxidation and precipitation, clarification, and carbon adsorption. These additional treatment steps will reduce the cyanide levels to meet the much higher discharge standards adhered to by Goldcorp.

Cyanide Oxidation Phase

The project began with treatability testing to determine an effective method to treat the cyanide and metals to achieve the desired concentrations. The goal was to find a process that would work consistently, have minimum system footprint, and to consider life cycle costs.

Available technologies were evaluated and then laboratory treatability testing was performed.. Further testing was then done at the mine site to be able to use fresh tailings water for the most accurate projection of reagent cost, process detention time requirements, and confirmation of final concentrations of the constituents of concern. The treatability study led to the chemical and physical system design.

In order to meet the final effluent limits for total, WAD and free cyanide, it was determined, through the lab treatability studies and on-site testing, that pH control and iron sludge adsorption, along with peroxide oxidation, copper sulfate catalysis and precipitation, would be the most effective treatment strategy. Iron sludge adsorption and the addition of the heavy metal chelating agent were selected to remove primary Hg.

The first phase, cyanide oxidation, reduces the cyanide to acceptable levels and reduces mercury. A treatment regime was developed for cyanide using peroxide oxidation with a copper catalyst, and precipitation. An organo sulfide chelating polymer was used to help reduce mercury concentrations down to very low levels as a polisher to the coagulant program determined during treatability studies. In testing, mercury was reduced to below detectable levels (0.0002 mg/L for this test).

Total cyanide concentrations in water from the tailings impoundment vary from 1.260 – 2.590 mg/L, with an average of 2.1950 mg/L — and WAD cyanide concentrations vary from 0.550 – 1.890 mg/L, with an average of 1.0150 mg/L. Mercury concentrations vary from 0.0039 – 0.0135 mg/L, with an average of 0.0074 mg/L.

Oxidation reduction to destroy the cyanide was evaluated with both sodium hypochlorite and hydrogen peroxide but there was a potential concern with potential chloride buildup over time in the tailings impoundment as well as other concerns with using sodium hypochlorite. The use of hydrogen peroxide as the oxidant was very successful and thus it was used as the primary oxidant.

Clarification Phase

The second treatment phase, clarification to remove the metals and sediments, is carried out by high-rate, sand-ballasted flocculation and settling technology.

In the sand-ballasted flocculation process, raw water is first mixed with a coagulant in a high-shear environment where it is retained for two minutes. In the next tank, the water is injected with a polymer along with microsand and mixed aggressively for approximately another two minutes. The water then enters a "maturation zone," where gentle shear is applied for an additional six minutes.

The microsand-ballasted flocs increase in size, trapping smaller flocs before the water enters the sedimentation tank, where the large flocs immediately begin to settle. The clarified water at this stage then counter flows upward through settling tubes to collection troughs where it can be diverted to various applications. The microsand and other solids in the ballasted flocs that settle in the bottom of the tank are then pumped to a hydrocyclone centrifuge. The microsand is cleaned and reinjected for reuse and the waste solids are removed. Additional microsand is added to the process periodically as make-up to replace the small amount of microsand that is lost during solids removal.

The technology has proven both flexible and versatile. The coagulation phase works on the total suspended solids (TSS) and chemically active contaminants. The polymeric flocculant ensures that the microsand bonds strongly to the flocculated solids. The solids by themselves are typically at or near the density of water, so they cannot settle rapidly without the added weight of the microsand (2.65 specific gravity). Once weighted with the tiny sand particles, the flocs sink immediately in the settling tank and therefore allows the clarifier to operate at rise rates typically ranging from 15 – 30 GPM/ft^2 versus conventional clarifiers that operate at rise rates of 0.25 – 1.0 GPM/ft^2.

Multi-Task Technology

The sand-ballasted flocculation process serves not only as an effective high-rate clarifier but also as a highly versatile chemical reaction vessel. Depending on pH conditions, colloidal and dissolved metals in the influent can be precipitated using classic and familiar chemical treatment methods for efficient sand-ballasted removal in the settling step. Because retention times in the system are very rapid (minutes instead of hours), the technology is extremely compact, providing increased capacity without the large surface area requirements of traditional flocculation/sedimentation systems.

The compact size of the sand-ballasted flocculation system resulted in a significantly lower total installed cost impact on the project as well as a reduction in the footprint needed. With the mountainous terrain where the mine is located, level areas are minimal unless substantial earth moving is performed. The smaller footprint allowed the system to be installed in a reduced footprint and the new treatment plant was installed in a long narrow area adjacent to the tailings impoundment.

Solids Polishing

Following clarification a disc filter is used to polish the effluent for removal of suspended solids. The disc filter is a mechanical, self cleaning filter that works without pressure to force water from a center drum through partially submerged vertical disc elements attached to the drum. Each disc consists of eight filter segments. Solids are separated from the water by micro-screen cloth mounted on the two sides of each segment. The pore size of the micro-screen is 10 micron. Once separated, the solids are rinsed off of the filter elements into a collection trough from where they are discharged. Solids from the process are placed back into the tailings impoundment.

The units use a portion of the filtered effluent to spray over the filters and backwash them as they are in the process of treating the feed stream, thereby allowing for continuous operation as well as continuous cleaning. The compact design of the disc filter configuration provides two to three times more filter area compared with pressure filters of the same external footprint.

Carbon Adsorption Phase

The third and final treatment phase is carbon adsorption. Here, water is pumped through columns containing sulfur impregnated activated carbon, accumulating substances in the filter.

Through adsorption, the contaminant material physically attaches to the meso-pores and micro-pores of the active carbon. Depending on the mercury concentration and chemistry removal efficiencies, it may not be necessary to rely on carbon filters for secondary mercury treatment. But because Goldcorp wants to be 100 percent certain that the discharge at the mine meets its own stringent standards 100 percent of the time, it was decided to include it as a precautionary measure. The carbon system is only used during discharge to the environment. Typical operation is to reuse the treated water back into the mill process.

Summary

The cyanide removal process uses oxidation by hydrogen peroxide with copper sulfate as a catalyst. The use of the copper along with an iron coagulant also helps to precipitate some cyanide complexes, so with oxidation and precipitation, the cyanide target levels are met. Lab testing determined this to be an effective treatment approach and actual operation has confirmed it to be successful.

The iron coagulant also provides a coprecipitation / adsorption mechanism for metals removal. Polishing to even lower levels using an organic sulfur precipitation compound allows Marlin to meet their objections for metals removal.

Treatment results are summarized in the following charts:

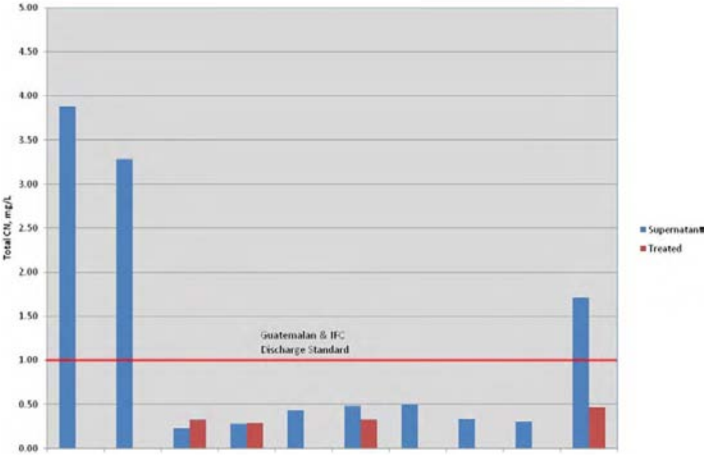

Figure 1 *Total CN Pre vs. Post Treatment, 2009*

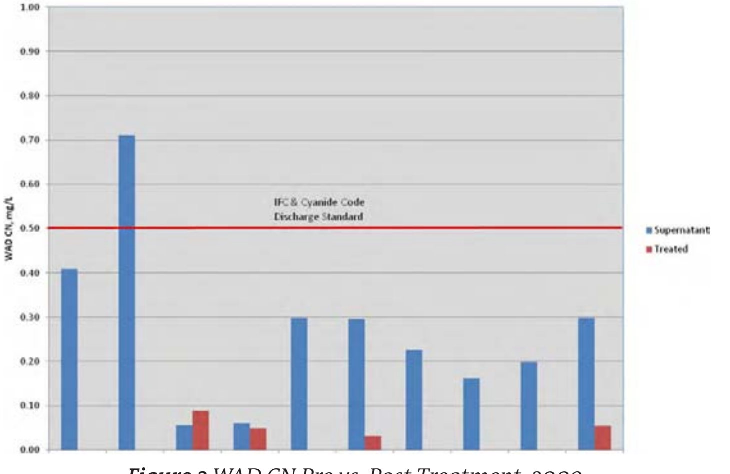

Figure 2 *WAD CN Pre vs. Post Treatment, 2009*

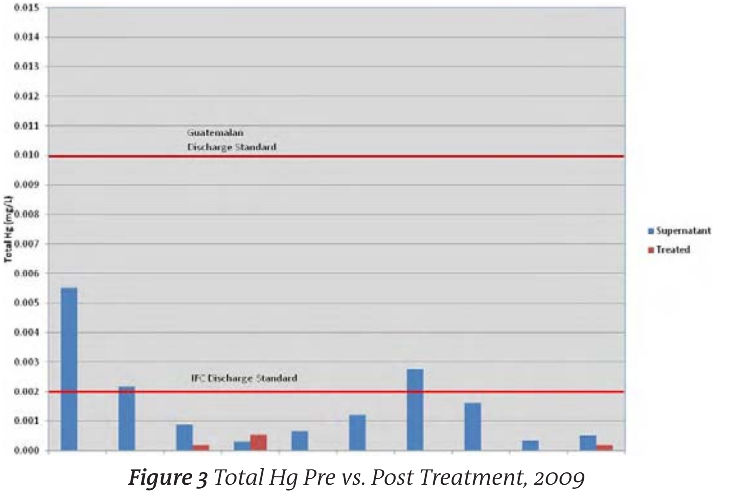

Figure 3 *Total Hg Pre vs. Post Treatment, 2009*