Three-Phase Mining Effluent Treatment Plant To Meet Stringent Standards

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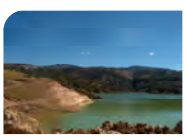
Discussion Outline

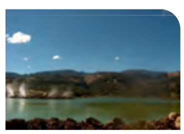
- Paper and Project Description
- Paper and Project Objective
- Site Descriptions
- Cyanide Oxidation Phase
- Clarification Phase
- Solids Removal Phase
- Carbon Adsorption Phase

Paper & Project Objective

- Discuss high-rate ballasted flocculation technology, cyanide oxidation and filtration/carbon adsorption make up an advanced, three-phase cyanide and metals removal process.
- Project scope was the development of a treatment solution and subsequent execution of that solutions at the Marlin Mine owned by Goldcorp in Guatemala. The project was executed in 2008/2009.



Tailings Pond



Paper & Project Objective

- Objective of the paper was to describe the treatment processes required to treat the tailings pond water to allow the treated water to be used for reuse back into the mill process or for discharge to the environment that is in compliance with the International Cyanide Code and self imposed Goldcorp standards.
- The project objective was to perform treatability testing off site and at the site to confidently arrive at a treatment solution that met the reuse and compliance objectives at a reasonable total installed cost and an installed system that allows for easy operation and maintenance by a multinational work force.

Mine Site Description

- **Montana Exploradora de Guatemala, S.A., Marlin Mine. Goldcorp property in the western highlands of Guatemala.**
- **Combination open-pit and underground gold and silver mine.**
- **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 (INCO) prior to discharge to the mine's tailings impoundment.**

Mill Description

- **The mill is designed to treat a minimal 1.82 million tons per year of ore.**
- **Ore is fed through a crusher prior to being introduced into the grinding circuit.**
- **Milling is conducted in a semi-autogenous grinding mill/ball mill circuit. The pulp produced by the milling is subjected to tank leaching with cyanide. After leaching the ore in the large tanks, the pulp is 'washed' in a series of settling units (counter-current decantation). This effectively produces two products: a clear gold and silver bearing solution and also a pulp without precious metal values. The gold and silver solution is sent to the refinery where the metals are precipitated out of solution through the addition of zinc. The precipitate is filtered and smelted to produce dore bars.**

Treatment Descriptions

- **The INCO plant is very effective in treating tailings for WAD cyanide significantly below the 50 ppm as required by the IFC guideline for open waters. Additionally, the WAD cyanide levels in the TSF are typically below all effluent standards, but the total cyanide levels range from 1 ppm to 5 ppm, where the effluent standard is 1 ppm.**
- **"To further reduce the total cyanide levels as required for discharge, a secondary water treatment plant was constructed. The plant includes an oxidation step followed by a clarification/filtration step. Finally the secondary water treatment plant includes a carbon adsorption process, however according to the test work conducted this will be only used as a contingency or polishing step when necessary. The secondary water treatment plant is operational; however, no discharge to the environment has occurred to date. (Goldcorp Annual Mining Report – 2008)"**

Tailings Storage Facility (TSF)

- **The impoundment (TSF) currently has a capacity of 4 million cubic meters and is expected to expand to nearly 20 million cubic meters by the end of the mine's life.**

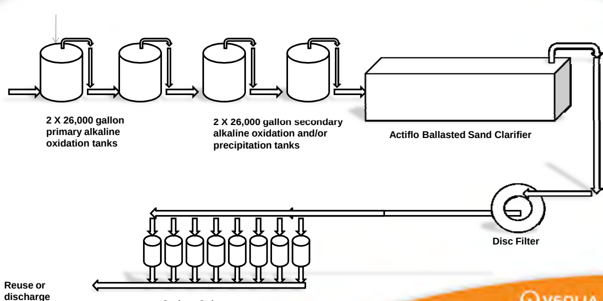
Water Quality Characteristics

- Influent water characteristics:
  - Flow 2,200 gallons per minute (400 m3/hr)
  - Total Cyanide: 1.26 – 2.59 mg/L, 2.195 mg/L avg
  - WAD: 0.55 – 1.89 mg/L, 1.015 mg/L avg
  - Mercury: 0.0039 – 0.0135 mg/L, 0.0074 mg/L avg
- Discharge limits:
  - Flow 2,200 gallons per minute (400 m3/hr)
  - Total Cyanide: < 1.0 mg/L
  - Free Cyanide: < 0.1 mg/L
  - WAD: < 0.5 mg/L
  - Mercury: < 0.002 mg/L

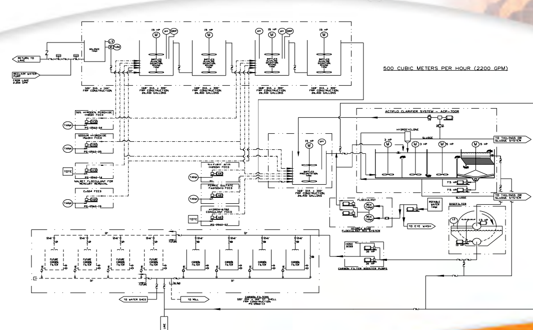
Water Quality Characteristics, continued

				Reclaim Water Summary		
		World Bank Standards	Marn Standards	Average	High	Low
pH del campo	S.U.	6-9	6-9	8.96	9.09	8.82
Cianuro Total (total cyanide)	mg/L	1.0	1.0	2.195	2.59	1.26
Cianuro WAD (WAD cyanide)	mg/L	0.5	-	1.015	1.89	0.55
Sulfatos	mg/L			2108	2320	1810
Sólidos Suspendidos Totales (TSS)	mg/L	50	100	15.5	36	6
TDS (calculated)	mg/L			3293	3660	2880
Grasas y Aceites (oil and grease)	mg/L	20	10	2.02	5.1	<2.0
Arsénico Total (arsenic)	mg/L	1.0	0.1	0.0071	0.008	0.0062
Cadmio Disuelto	mg/L			0.0003	0.0007	<0.0002
Cadmio Total (cadmium)	mg/L	0.1	0.1	0.0006	0.001	<0.0002
Cobre Disuelto	mg/L			0.5475	1.2	0.15
Cobre Total (copper)	mg/L	0.3		0.59	1.23	0.18
Cromo Disuelto	mg/L			<0.020	<0.020	<0.020
Cromo Total (chromium)	mg/L	1.0	-	<0.020	<0.020	<0.020
Hierro Disuelto	mg/L			0.5075	0.76	0.37
Hierro Total (iron)	mg/L	2.0	-	1.1125	1.61	0.9
Mercurio Disuelto	mg/L			0.003925	0.0106	0.0016
Mercurio Total (mercury)	mg/L	0.002	0.002	0.00735	0.0135	0.0039
Níquel Disuelto	mg/L			<0.020	<0.020	<0.020
Níquel Total (nickel)	mg/L	0.5	2.0	<0.020	0.02	<0.020
Plomo Disuelto	mg/L			<0.0002	0.0012	<0.0001
Plomo Total (lead)	mg/L	0.6	0.4	0.0004	0.0008	<0.0001
Zinc Disuelto	mg/L			<0.020	<0.020	<0.020
Zinc Total	mg/L	1.0	10.0	0.02	0.03	<0.020

Process Flow Diagram



Process Flow Diagram



Cyanide Oxidation Phase

- Cyanide removal will be accomplished by a single stage chemical oxidation treatment system. Free and weakly complexed metal cyanides follow the following chemical reactions when oxidized with hydrogen peroxide (50% H_2O_2):

$$CN^- + H_2O_2 \leftrightarrow OCN^- + H_2O$$
$$M(CN)_4^{-2} + 4H_2O_2 + 2OH^- \leftrightarrow 4\,OCN^- + 4\,H_2O + M(OH)_2 \text{ (solid)}$$

- A soluble copper catalyst (3% copper sulphate pentahydrate, $CuSO_4 \cdot 5H_2O$) is used to increase the reaction rate. Metals are precipitated in a solid form upon pH adjustment of the solution. Ideal pH depends on the specific metal removal. Metal precipitation pH is between 9.0 and 9.5 standard units.

Cyanide Oxidation Phase, continued

- Cyanate (OCN^-) produced will hydrolyze to form ammonia and bicarbonate in the following reaction:

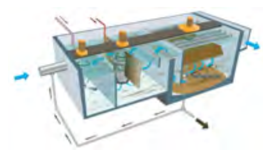
$$OCN^- + H^+ + 2H_2O \leftrightarrow HCO_3^- + NH_4^+$$

- A heavy metal chelating and precipitating agent is also added upstream of the clarifier to assist in the formation of precipitated solids for subsequent removal by the clarification and solids removal phase.

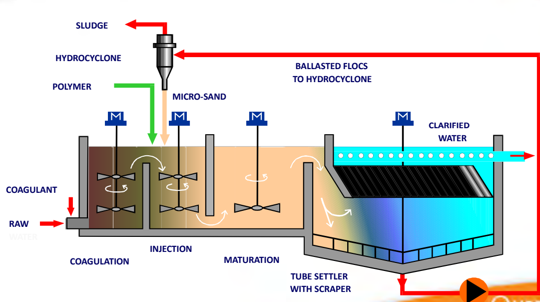
Oxidation & Precipitation Tanks

Clarification Phase

- The treatment process is also designed to remove total suspended solids (TSS) through coagulation, clarification, and filtration.
- Inlet water TSS varies from 6 to 36 ppm with an average of 15.5 ppm. Solids will also be generated from the use of a heavy metal chelating and precipitating agent, inorganic coagulant (ferric sulfate), and organic coagulant for treatment. Removed solids are sent to the TSF.
- A ballasted sand, high rate sludge recirculating clarifier (Actiflo® Clarifier) was chosen as the clarification technology due to its performance and small footprint. The small footprint reduced the total installed cost and allowed installation next to the TSF .

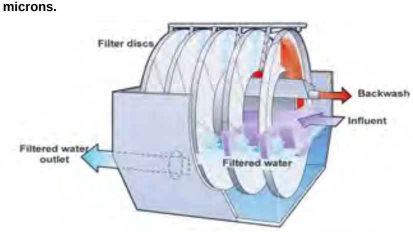


Clarification Phase, continued



Solids Polishing Phase

- Fine solids removal will occur through filtration. Clarified water from the clarifier is filtered utilizing a Rotating Disc Filter. The Hydrotech Discfilter is a rotating disc filter fitted with microscreen media to allow filtration of particles to 10 microns.



Solids Polishing Phase, continued

Discfilter Benefits

- 70-80% smaller footprint than sand filters
  - Example: 2,992 GPM
- California Title 22 approved
- Low installation & operational cost
- Low operating head loss
  - 7.9 – 11.8 inches
- Simple design
  - Stainless Steel Construction
- Flexibility
  - Modular construction

Area for typical Sand Filter

Area for Discfilter

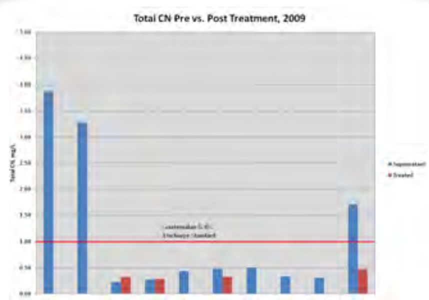
Solids Polishing Phase, continued

- Backwash water from the disc filter is < 3% of the total treated flow of the unit.
- Continuous filtration during the backwash cycle. Backwash water is sent back to the TSF.
- Treated water is used for backwash and is sourced from the unit itself with its own dedicated backwash pump.

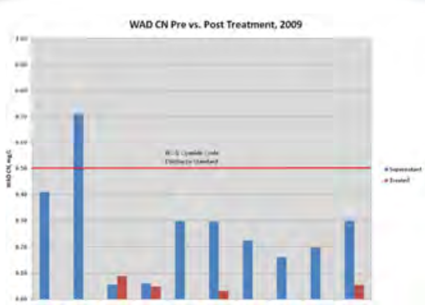
Carbon Adsorption Phase

- Primary mercury removal will be accomplished with the heavy metal chelating and precipitation agent.
- ***Secondary*** mercury treatment will be with carbon columns, 8 FRP columns, 120” diameter X 144” height operating in parallel.
- The carbon columns were provided as part of the solution in order to be conservative and insure compliance with the mercury discharge limits.
- Sulfur impregnated activated carbon was used in the columns.
- The mercury chemical reaction is:
  Hg + S ‹--› HgS

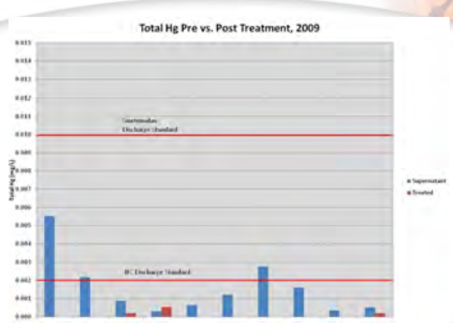
Total CN Pre vs. Post Treatment, 2009



WAD CN Pre vs. Post Treatment, 2009

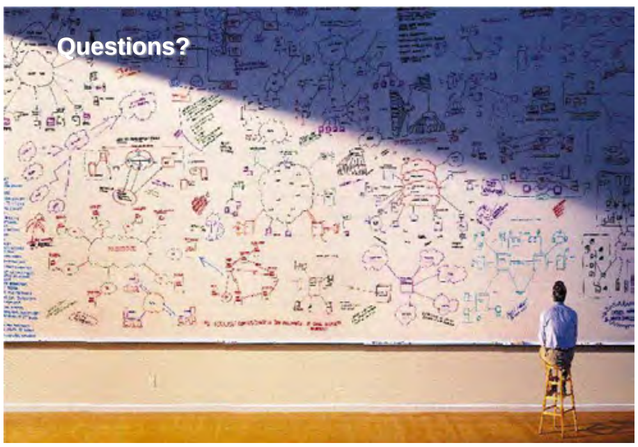


Total Mercury Pre vs. Post Treatment, 2009




Completed Treatment Plant


Completed Treatment Plant


Questions?