

Mitigating Environmental Impact Of Gold Mine Wastewater Through Ozone Oxidation And Aquifer Re-injection

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ABSTRACT

US Environment Protection Agency (USEPA) regulations require mining operations to remediate their waste streams prior to environmental discharge. Wastewater streams from gold mine operations can be particularly toxic due to the potential for cyanide contamination and the concentration of metals contained in the wastewater effluent.

This paper reviews the challenges and success of installing and operating an ozone oxidation system for wastewater remediation at a gold mine located in a remote region of Alaska. Cyanide leaching, carbon in pulp (CIP) and electrowinning processes utilized to extract gold from the mine's ore are reviewed. The remediation of metals and arsenic from the mine's wastewater dewatering process, utilizing ozone oxidation chemistry and ultrafiltration prior to reinjection into a local aquifer, are discussed in detail. The unique equipment designs to ensure reliability of a remote and isolated ozone system are included in this review.

Key Words

Alaska; antimony; arsenic; cyanide; GDT; gold; Mazzei; oxidation; ozone

The history of gold mining is rich in Nome, Alaska USA. Gold deposits discovered in 1899, just North of the future site of Nome, were the start of one of Alaska's biggest gold rush. More than \$ 1 million US dollars worth of gold was extracted from Nome's beach sands in the first year of the rush. Placer mining, a method of screening out gold nuggets from creek and river sands, continues today in Nome, with over 3.6 million troy ounces having been recovered since the early days of the gold rush [2].

In 1908 a USGS Geologist identified a cluster of low grade gold deposits 13 km North of Nome. These deposits remained unexploited until the fall of 2003, when a mining company requested a geotechnical exploration of the region to consider the feasibility of utilizing open pit mining to extract the ore. The study estimated that the proposed mine would produce an annual yield of 100,000 troy ounces of gold annually [7].

On site construction of the mining facility was initiated in 2005, with the first ingot poured on October 1, 2008. Future revenue from the mine has been estimated at 25 - 35 million US

dollars per year. However, the pathway to this multimillion dollar “pot of gold” was not without significant challenges.

Public Outcry: Hazards Of Cyanide Leaching

The July 27th 2006 edition the Nome Nugget, Alaska’s oldest newspaper, took a critical look at the environmental safety of the mines proposed cyanide leaching process. The article, “Corporate Greed VS Nome , Alaska Residents?” , was a critical expose on the potential hazards of cyanide, citing past incidents of cyanide spills at 72 US mining operations and questioning the wisdom of storing the more than 9 million tons of cyanide contaminated tailings that would accumulate over the mine’s projected 5 years of operation [5]

Cyanide Leaching & Carbon In Pulp Process

The mining project was designed to utilize cyanide leaching and a carbon in pulp (CIP) process to extract gold from excavated ore. The CIP process begins with the mixing of a crushed ore slurry with a 1% solution of alkaline, sodium cyanide. The cyanide leaches gold from the ore to produce a soluble aurocyanide complex, $\text{Au}(\text{CN}_2)^-$ (Figure No. 1: Elsner’s equation for the dissolution of gold using aerated alkaline cyanide).[8]

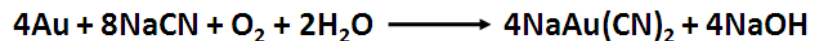


Figure 1.

Activated hard carbon particles mixed into the cyanide slurry adsorb the gold, forming a thick pulp solution. The gold saturated 10-16 mesh carbon is removed from the 100 mesh ore slurry by screening; then immersed in a 100 °C alkaline cyanide solution to re-solubilize the gold [8].

Electrowinning

High purity gold is collected by passing the aurocyanide solution through a packed bed of electrolytic cells. This process of stripping gold from the cyanide solution, called electrowinning, utilizes electrolysis to collect metal ions at the cathodes of the electrolytic cells. Once saturated, the cathodes are removed and placed in furnaces where they are heated to 2,000 F to remove the gold. Ingots produced by this method typically assay at a 90 – 93% purity [3, 8]. The stripped cyanide is returned to the CIP process, circulating between the leach ponds and electrowinning cells in a continuous closed loop.

Environmental Safety

To limit the environmental impact of the mining operation, the mine took stringent safety measures to isolate chemical processes and wastewater streams from the local environment. With the exception of its solids dewatering process, the mine was designed to operate as a closed system, removing and storing tailings and solids on site, and recycling fluids and chemicals in a continuous closed loop operation.

The majority of fluid from the dewatering process goes directly into the tailings pond, however the pond has a finite capacity, losing water only through natural evaporation. The excess dewatering effluent produces a 100 - 350 gpm (79.5 m³/hr) waste stream which must be processed and discharged from the mining operation.

At the time of this writing, the primary contaminants found in the dewatering stream consisted of measurable concentrations of antimony and arsenic, with cyanide and cyanide compounds below detection limits.

Ground Water Injection and USEPA Compliance

To avoid the open discharge of dewatering effluent, the mine applied for a permit to establish an Underground Injection Control (UIC) program. The mine's proposed UIC program, authorized by part C of the US Safe Water Drinking Act, requested permitting for 15, Class V disposal wells to inject treated dewatering effluent into the site's upper bedrock aquifer [9]. Class V injection wells, by definition under USEPA Title 40 C.F.R. § 144.33, are used for disposal of fluids into current or future underground sources of drinking water. Consequently, the mine's effluent had to comply with the USEPA's Maximum Contaminant Levels (MCLs) for drinking water, at the point of well injection.

Location/Environmental Concerns Dictate Design

The range of treatment methods that the mine could utilize to remediate the dewatering waste stream, were limited by environmental concerns and the remote location of the mining operation. Backwash filtration systems, ion exchange media that produced a chemical regenerative stream and any other treatment process that generated a secondary waste stream was eliminated from consideration during the design phase of the wastewater treatment system

Treatment designs requiring material replenishment, such as modular ion exchange vessels, chlorine dioxide generators or chemical oxidants, were also not considered, because of the isolation of the mining site during winter time operation. The Town of Nome, located on the Seward Peninsula by the Bering Sea, lacks a railroad and interstate highway and can only be

reached by ship or plane during the brief summer months, and only by plane when winter ice floes make its port inaccessible to cargo ships (Figures 2 & 3. Nome, Alaska region during Iditarod dog sled race & Alaska glaciers).



Figure 2.



Figure 3.

Ozone oxidation followed by lamella clarification, then ultra-filtration, was selected as the best treatment design that would ensure mine effluent met drinking water quality standards at the point of aquifer injection. The ability to provide on-site generation of both oxygen and ozone was a strong plus in favor of the ozone oxidation system [1].

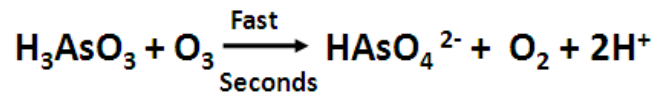


Figure 4.

Pre-filter Ozone Oxidation

The primary contaminants in the mine's effluent, antimony and arsenic, are both readily oxidized by ozone (Figure 4. Ozone oxidation of As ⁺³ to As ⁺⁶ @ pH=8.5)[4]. Ozone would additionally detoxify any trace amounts of cyanide contained in the dewatering wastewater stream (Figure 5. Ozone oxidation of cyanide to cyanate.)[6,7].

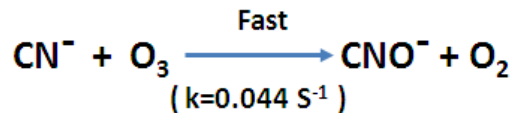


Figure 5.

To simplify the installation and operation of the ozone oxidation system, the equipment was provided as a pre-assembled, validated ozone oxidation system housed in an 8' (2.4 m) wide x 40' (12.2 m) long x 8' (2.4 m) high, heated cargo container. The system included an air compressor, an oxygen concentrator, a 945 g/hr, 10% wt ozone generator, a cooling water chiller, an ozone contacting system, and instrumentation.

Space limitations within the cargo container required a high efficiency, small footprint ozone contacting and off gas design. A review of the available ozone contacting options resulted in the selection of a high efficiency GDT™ process ozone contacting and degasification skid. The skid utilized pressurized and high velocity gas mixing, to provide a rapid mass transfer of ozone gas to solution. Transfer was followed by the immediate removal and destruction of ozone off gas utilizing a GDT™ Degas Separator. (Figures 6 & 7: GDT™ process skid and ozone transfer efficiency design).



Figure 6.

Equipment Reliability

Mining productivity was depended on the continuous, successful operation of the wastewater treatment system. An unexpected shutdown of the ozone oxidation system due to component failure would result in a significant slow down; possibly the shutdown of mining operations. Consequently, the wastewater design engineer demanded some fail safe features be built into the ozone system. Something that went beyond the stocking of spare parts. One of the more unique fail safe features of the system was the utilization of an ozone generator with self protecting ozone generating cells [1].

The ozone generating cell is the site of ozone creation within an ozone generator. The constant electrical discharge across the cell's dielectric material, over time, causes material fatigue and, eventually, points of failure. In an ozone generator, the failure of the cell's dielectric material at any point causes an uncontrolled electrical arc to ground, creating a short circuit in the generators electrical power grid.

In a standard, commercially available ozone generator, the short circuit trips a fuse, taking the cell permanently out of service. This electrical fault often shuts down the entire ozone generator, requiring an onsite operator to restart the ozone generating system. Once the generator is re-started, the cell that caused the electrical fault is permanently out of the generators electrical grid and is unable to produce ozone. On the small 50 ppd (945 g/hr) ozone generator utilized by the mine's wastewater treatment system, the number of cells were few in number, consequently the loss of a single cell would significantly reduce ozone output,

limiting the treatment capacity of the wastewater system which, in turn, would limit the processing of ore and the production of gold.

To ensure against an unexpected system shutdown, the design engineer selected a Mitsubishi Electric ozone generator that was designed with self protecting ozone generating cells. The generator, at the first instance of a cells electrical arc, shuts down, isolates and removes the site of failure from the cells electrical circuit, then automatically returns the cell and ozone generator to service. The entire sequence occurs over a period of seconds, with no significant interruption in ozone production. The cell that caused the fault is restored to service and continues to produce better than 98% of its original ozone output, which allows the generator to continue to provide better than 99% of its peak design dosage [1].

Mazzei Injector Corporation GDT Process Transfer Efficiency			
Prepared For:	Ozone System Supplier		
Project:	Gold Mine Project		
Purpose For Ozonation:	945 g/hr @ 10% Wt		
Date:			
Operating Parameter	Units	Value	Comments
GDT process sidestream	GPM	253	Gas mixing velocity > 70 fps (> 21 m/sec)
Gas-Water Mixing Pressure	PSIG	40	Flash Reactor working pressure (2.8 barg)
Applied Ozone Dose	mg/l	16.45	
Ozone Gas Concentration	wt %	10	
Expected Ozone Demand Ratio, mg/l/mg/l		0.35	mg/l Demand/mg/l applied: <u>Determined Empirically</u>
Calculations			
Required Ozone Injection Rate	g/Hr	945	
Required Ozone Gas Flow	SCFM	4.00	
Calculated Gas/Liquid Ratio	Vg/Vl	0.12	G/L at injector
Mass Transfer Efficiency, MTE	%	99.56	Ozone Off-Gas/Ozone Feed
Initial Ozone Residual: Separator Effluent	mg/l	10.60	Residual after transfer and demand consumption
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Figure 7.

Conclusion

The successful utilization of ozone at a remote mining operation in Nome, Alaska is just one example of how recent advances in the design of ozone generators and their contacting systems has resulted in an increased commercial availability of reliable, small footprint, turn-key ozone systems. As industrial operations and their local communities continue to look for the “green solution” to their environmental concerns, ozone will be playing an increasingly larger role in the design of industrial wastewater treatment systems.

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