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3.2 OPTIMIZATION OF ARSENIC REMOVAL IN THE MILLING PROCESS AT RED LAKE MINE.

PRESENTER: JUNXIANG GUO, RED LAKE MINE, GOLDCORP INC.

ABSTRACT

The sustainable growth of the gold mining industry depends to a significant degree on its ability to develop proactive strategies to ensure environmental compliance. One of the initiatives taken by Goldcorp was the set-up of an Environmental Metallurgy Program at its Red Lake Mine in February, 2001. One of the priorities in the present environmental metallurgical work is to optimize arsenic removal in the milling process.

At Red Lake Mine, 60.9% of gold is recovered by gravity concentration and 30.0% of gold is recovered by cyanidation (CIP). The cyanide residue slurry is then treated in the Inco SO_2/AIR cyanide destruction circuit on a continuous basis. Ferric sulfate solution is added after cyanide destruction process to precipitate arsenic in the solution part of the slurry. Ferric treatment is followed by the flotation of the cyanide residue to recover the additional gold associated with auriferous arsenopyrite and pyrite. The flotation is carried out in an alkaline circuit adjusted with lime (pH 9~11). About 45% of scavenger tails are used to make backfill paste.

The intent of this presentation will be to review the process chemistry and discuss the effects of varied operating conditions throughout the milling process at Red Lake Mine on arsenic removal. The results show that under proper operating conditions the modified arsenic treatment train in the milling process can effectively remove arsenic from the effluent and the precipitates thus produced are believed to be more stable.

Questions/comments:

Coumans	If 50% of the arsenic was removed, where did it go?
Guo	It was absorbed by fine carbon in the presence of copper sulfate which forms a stable precipitate.

3.3 CONTROLS GOVERNING THE REMOBILIZATION OF ARSENIC FROM SUBMERGED TAILINGS: CASE STUDIES FROM BALMER LAKE AND GOLDCORP TAILINGS POND

PRESENTER: ALAN MARTIN, LORAX ENVIRONMENTAL SERVICES LTD.

ABSTRACT

Due to the metallurgical processing of As-bearing ores and associated effluent treatment, As is commonly associated with Fe(III) solid phases in final tailings discharges, including: 1) ore pre-treatment products (*e.g.*, hematite) resulting from pressure oxidation and roasting; 2) amorphous Fe-(oxy)hydroxides which reprecipitate within the mill stream; and 3) treatment products associated with Fe/As removal (*e.g.*, ferric arsenate). Although Fe-oxide phases are relatively stable in oxygenated environments at pH>4.5 (*e.g.*, unsaturated neutral-pH tailings), they may become destabilized in suboxic settings (*e.g.*, permanently saturated tailings).

In permanently-saturated tailings and lacustrine sediments, the mobility of As associated with labile Fe(III) phases is largely governed by the redox cycling of Fe, in which both elements follow a pattern of remobilization in suboxic horizons (*i.e.*, reductive-dissolution), diffusion toward the tailings-water interface,

and reprecipitation in oxic interfacial zones (Azcue et al., 1994; Martin and Pedersen, 2002; McCreadie et al., 2000). The depth of reductive dissolution of Fe(III), and hence As release to porewaters, is dependent on the sediment oxygen demand (SOD). In most aquatic settings, the magnitude of the SOD is dictated by the oxidation rate of organic matter (OM) at the tailings-water interface. In environments characterized by relatively low accumulation rates of OM, the Fe(III) redoxcline and depth of As release may be present at over a decimetre below the benthic boundary (Widerlund and Ingri, 1995). Conversely, in regions characterized by high primary productivity (*e.g.*, high algal growth) such as coastal margins and eutrophic lakes, As release to suboxic porewaters can occur within a few millimetres of fully-oxygenated bottom waters (Martin and Pedersen, 2002; Peterson and Carpenter, 1986).

The relationship between biological productivity (*e.g.*, phytoplankton production), sediment redox chemistry and As mobility has important implications with respect to the release of As across the sediment-water interface. For example, sediments characterized by relatively low SOD and a correspondingly thick zone of oxic sediments have a greater capacity to re-sorb upward diffusing As, thereby limiting the diffusive transport of As into bottom waters. Conversely, under conditions of greater sediment oxygen demand in which the depth of the Fe(III) redoxcline is in close proximity to the sediment-water interface, the efficiency of scavenging mechanisms is significantly reduced. This, in concert with larger concentration gradients across the benthic boundary, results in a greater flux of As to the water column (Martin and Pedersen, 2002).

In mining-impacted systems, the loading of algal nutrients to contaminated systems has the potential to amplify the release of sediment-derived As via alteration of sedimentary redox conditions. High concentrations of N and P, for example, often accompany mine effluents due to addition of blasting reagents, domestic greywaters, sewage and treatment products (*e.g.*, ammonia derived from cyanide destruction in INCO-SO_2 processing) (Devuyst et al., 1982). The increased production and downward flux of OM associated with lake eutrophication has been shown to influence the oxygen demand at the water-sediment interface (Kuhn and Sigg, 1993). Accordingly, the post-depositional stability of As that is reversibly associated with Fe oxides will respond to such perturbations in biological production.

In Balmer Lake and Goldcorp's tailings management area (TMA), the remobilization of As from the tailings contributes to elevated levels of As in surface waters (Lorax, 2001; Martin and Pedersen, 2002). In both cases, porewater and mineralogical data indicate that the remobilization of As occurs through the reductive dissolution of Fe-oxides associated with relict roaster tailings. Similar controls have been established for the remobilization of As from saturated tailings in the Campbell Mine tailings area (McCreadie et al., 2000). Under the current redox regime in Balmer Lake and Goldcorp's TMA, the reductive dissolution of As-bearing Fe(III)-oxides occurs in close proximity to the sediment-water interface. The thin veneer of oxic sediments limits the extent to which As can be re-sorbed in the interfacial horizons, and as a result, a large proportion of the remobilized As escapes into the water column. The shallow depth of As remobilization in Balmer Lake sediments, and the associated flux of As to the water column, is sustained by high oxidation rates of organic matter in the surface sediments. In turn, high biological production in the lake is sustained by loadings of P from mine-derived sources. Indeed, examination of the relationship between summer average chlorophyll *a* and total P at spring overturn in surface waters demonstrates that Balmer Lake is currently eutrophic as a result of mining-derived inputs of P. In contrast, unperturbed shield lakes in northwestern Ontario are typically oligotrophic (Armstrong and Schindler, 1971).

The results suggest that actively pushing Balmer Lake and the TMA towards oligotrophy by reducing non-natural P loadings to these systems will decrease rates of *in situ* biological production and associated sediment oxygen demand, which will in turn result in increased thickness of the aerobic zone and enhanced As scavenging (Martin and Pedersen, in review). These conclusions are supported by other data which indicate that the flux of As to the water column is lower under less reducing sedimentary conditions in which the depth of the Fe(III) redox-cline lies several centimetres below the benthic boundary (Martin and Pedersen, 2002).

Collectively, the results highlight the conclusion that the chemical stability of As in submerged tailings reflects both: 1) the solid-phase characteristics of the tailings material; and 2) the physical, chemical and biological characteristics of the depositional environment. In particular, the data indicate that the stability of redox-sensitive tailings phases and biological processes are intimately linked. Accordingly, for operations which propose to discharge Fe(III)-As products to aquatic settings, care must be taken assess how redox conditions will influence the stability of tailings solids. In addition, attention should be given to the potential changes in the redox environment which may occur during operational and closure phases. The data also highlight the need for the more wide-spread use and performance verification of alternative forms of tailings storage (*e.g.*, dry stacking) for materials which are unstable in suboxic conditions.

References.

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PRESENTATION : See Appendix C

Questions/comments:

Higgs	Is consolidation occurring in the sediments expelling the pore water?
Martin	Possibly, there is very little tailings accumulation occurring in the secondary pond.
Martel	Are the models validated with other parameters?
Q. Wang	Are there specific release rates?
Martin	There are no phase specific release rates, they are relative to input.

3.5 IMPLICATIONS OF THE BEHAVIOR OF ARSENIC IN MINE TAILINGS UNDER POST-DEPOSITIONAL CONDITIONS

PRESENTER: DESIREE MEILLEUR, GOLDCORP/ UNIVERSITY OF BRITISH COLUMBIA

ABSTRACT

Arsenic is associated with iron oxide phases in the roaster tailings present in both the Primary and Secondary Ponds located in the active Red Lake Mine tailings management area. These iron oxide phases represent a relatively stable sink for arsenic under oxidizing conditions. Numerous researchers, however, have observed reductive dissolution of iron oxide phases under anoxic conditions, resulting in the release of adsorbed and/or structurally bound arsenic. In the Secondary Pond, post-depositional reducing conditions have developed as a result of flooding of the tailings surface and increased biological activity. Distinct seasonal trends have been observed in arsenic concentration in the effluent from the tailings management area due to the reductive dissolution, with significantly higher arsenic concentrations seen during the warmer summer months. It has been concluded by several authors that reducing conditions lead to the mobilization of arsenic and an attempt should be made to prevent reducing conditions from occurring.

In tailings impoundments, the onset of post depositional reducing conditions is likely inevitable, even if the tailings are not stored underwater, due to the development of a water table and saturated conditions at some depth within the tailings deposit. It is therefore desirable to find a method to stabilize arsenic in an anoxic environment. Under strongly reducing conditions it is known that sulphate is microbially reduced to sulphide, resulting in the precipitation of insoluble metal sulphides, such as pyrite. Arsenic can coprecipitate with metal sulphides and/or adsorb onto the surface of these metal sulphides, resulting in its removal from solution.

At many locations it appears as if this process is not occurring as elevated arsenic concentrations are reported to develop after reducing conditions set in. It is not clear as to why arsenic is not being removed via metal sulphide precipitation and it is necessary to investigate if it is possible to promote this process to take place. Potential treatments that would be necessary to bring about the removal of arsenic from solution via reduction will be identified and investigated through insitu column experiments and laboratory testing.

Additional Comments:

Desiree also talked about four test columns of potential treatments;
Column 1 – Control
Column 2 – Peat, a little change was observed on the bottom and no change in the middle of the column
Column 3 – Peat & gypsum, column bottom saw a strong increase in iron & arsenic dissolution, and the middle of the column saw no change.
Column 4 – Peat, gypsum & zero valent iron, the arsenic was completely removed from the bottom and middle of the column.

PRESENTATION : See Appendix C

Questions/Comments:

Nicholson We have to have something to cause reducing conditions. Could we prevent reducing conditions by not putting in key ingredients i.e. a source of electrons. We should be careful in how we define this.

3.6 ARSENIC REMOVAL FROM MINING AND PROCESS WATERS

PRESENTER: JACK ADAMS, APPLIED BIOSCIENCES

Johanne,

I have found ths in my rummaging. Just for your FYI.

Melissa