Red Dog Mine
Closure and Reclamation Plan

SD E5: Assessment of Methods for Managing Post-Closure Water Treatment Sludge

Assessment of Methods for Managing Post-Closure Water Treatment Sludge Red Dog Mine, Alaska

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1 Introduction

The treatment of water is expected to continue long after closure of the Red Dog mine. As discussed in a separate report (SENES 2004), lime neutralization is likely to be the treatment process of choice. That process converts metals and acidity in the water to a sludge. This report reviews methods for long-term management of the water treatment sludge at Red Dog mine. Specifically, it presents estimates of future sludge production rates, reviews methods for reducing sludge volumes, and discusses options for final disposal.

2 Estimates of Sludge Production

Sludge production from the treatment of acidic waters at the site is projected to range from about 2,000 tonnes per year to 18,000 tonnes per year, depending upon the degree of source control adopted in the closure plan. The lower range of production (2,000 tonnes/year) would occur if source controls (e.g. covers over the waste stockpiles) were able to reduce existing acidity by about 75%. In this case, sludge would consist primarily of zinc hydroxide with perhaps a small amount of iron hydroxide. The upper range of sludge production (18,000 tonnes/year) would apply if acid production were to remain at the same level as measured for 2003. In this case, sludge production would increase due to the precipitation of gypsum and the increased levels of zinc and iron hydroxide.

Currently, Water Treatment Plants #1 and #2 (WTP#1 and WTP#2) treat a mildly acidic water withdrawn from the tailings pond. The primary contaminant in the water is zinc, which precipitates as zinc hydroxide. The resulting sludge has a very low density (typically 2%-5% solids) and is pumped to the tailings pond. At closure, the recycle of water through the mill will stop and it is currently envisaged that treatment at WTP#1 will be discontinued. If source controls are not implemeneted, the tailings pond will become more acidic and contain much higher levels of sulfate, zinc and iron unless. With the higher levels of acidity in the tailings pond, WTP#2 will produce substantially more sludge at a higher density. (The density effect is discussed in Section 3.1 below.)

3 Dewatering and Concentration Methods

The following methods are used for sludge dewatering and concentration:

- Thickening
- Filtration (vacuum, pressure)
- Freezing
- Evaporation/Drying
- Gravity Consolidation

These methods are briefly reviewed in the following sections.

3.1 Thickening

The Red Dog mine currently employs a High Density Sludge lime treatment circuit, which has the capability to produce a thickened high density sludge. Currently, the metals loading to WTP#2 is low and a low density sludge is produced. However, at closure, as metals levels increase, it is projected that WTP#2 will produce a higher density sludge. Some modifications to the existing thickeners at Red Dog may be required to handle the dense sludges that will be produced at closure.

At the higher rate of sludge production (18,000 t/y), it is likely that a sludge with >20% solids will be formed. Similar HDS plants at other sites typically achieve sludge densities in that range (SENES, 1994). This sludge will contain a high percentage of gypsum along with iron and zinc hydroxide. At a sludge density of 20%, the annual sludge production will be 104,000 cubic yards.

At the lower sludge production rate (2,000 t/y), the sludge will likely continue to have a lower density of 2% to 5%, with zinc and iron hydroxide as the primary constituents. The annual volume would be 50,000 to 130,000 yd^3 (assuming 2 to 5% solids respectively).

3.2 Filtration

A number of filtration systems have been used to dewater sludges. The most common dewatering system is pressure filtration using filter presses or disc filters. Filter presses are commonly used in the metal plating industry to concentrate metal sludges prior to offsite disposal. They have also been used at mine sites; in one case to dewater sludges before disposal in an underground mine. Filter presses require power and would increase power demands at the treatment facility. As such, these systems would only likely be considered if rapid sludge volume reduction was required. The capital cost for new filters at the Red Dog site for a filter plant would be in the range of $15 million with annual operating costs of about $1.5 million (costs scaled from SENES 1994, advanced treatment scenario with pressure filters for high strength ARD wastewater). Capital costs could be reduced if the existing concentrate pressure filters can be adapted for this use.

3.3 Freezing

The most common application of "freeze dewatering" is to place sludges in thin layers in sludge ponds, and remove them after a winter season. When sludge freezes, water is released from the sludge matrix and forms layers of ice. The water melts and the sludge is increased in density. Dewatering beds below the sludge are an improvement, as they provide positive drainage and allow further densification of the sludge after it thaws. The typical dewatering bed would be a lined basin filled with a sand drainage layer and a series of plastic drainage pipes.

Specific testing of Red Dog sludges would be required to determine the expected final density and to optimize the design parameters for the freeze dewatering system. Dilute sludges are typically projected to undergo concentration by a factor of 10 (from 2 to 20%), while higher density sludges may double in density (from 20 to 40%). The resulting volumes are reviewed in Table 3.1.

Table 3.1: Estimated Sludge Volumes

Sludge Production (Dry t/y)	% Solids	Raw Volume (yd^3)	% Solids After Freeze Concentration	Dewatered Volume (yd^3)
2,000	2	129,000	20	4,800
18,000	20	104,000	40	44,000

A system would normally consist of at least two cells, one active and one idle. Sludge is applied to the operational cell over one effluent treatment period and removed the following year. Assuming a maximum depth of 2 ft/yr of sludge applied to the cell for dewatering, two cells each with a surface area of about 65,000 ft^2, or about 1.5 acres each, would be required. The capital costs of this system would be about $1,000,000. The major additional operating cost would be the removal of the sludge to final disposal.

3.4 Evaporation

Evaporation has been used for sludge concentration. The most common method in dry climates is to use passive solar evaporation to form a dry sludge for disposal. This would not be applicable to Red Dog. Sludge driers and other evaporative methods which use fuel (hydrocarbon or electrical) are prohibitively expensive and are only considered where other options are not available.

3.5 Gravity Consolidation

Gravity dewatering in storage cells is possible where there is sufficient time and adequate drainage is provided. The fine particulate size and colloidal nature of the Red Dog sludges will make gravity concentration inefficient as a primary dewatering method. However, it is realistic to consider gravity dewatering as a secondary benefit of an under-drainage in either a freeze dewatering cell or a final disposal site.

3.6 Other Methods

Other techniques that have been proposed for sludge dewatering include processes such as centrifuging, flotation, and electro-osmosis. These processes are unproven at the scale of the Red Dog operation.

4 Final Disposal Location & Methods

The following options have been proposed for long-term management of water treatment sludges:

- Disposal in the Tailings Pond
- Disposal in the Main Waste Stockpile and/or other waste rock piles
- Disposal in the Main and/or Aqqaluk pits
- Disposal in a purpose-built sludge management area
- Recycling

These options are addressed in the following section.

4.1 Tailings Pond

Tailings ponds are commonly used for sludge management (as is currently the case at Red Dog). Sludges are typically slurried with the tailings or pumped directly to the disposal area. For Red Dog, a primary issue with long-term disposal in the tailings basin is storage capacity. For example, current estimates put the storage capacity of the final pond at somewhere between 4,000,000 and 5,000,000 cubic yards. Assuming that about half of the pond could be isolated and used for sludge disposal, there would be room for roughly 20 years sludge production at 130,000 yd^3/year. Raising of the Main Dam and Back Dam could be considered if additional sludge storage capacity was necessary.

The tailings pond appears to be acceptable for sludge disposal use at closure. However, either another site would be required or the dams would need to be raised to store sludge production over the long term.

4.2 Waste Rock Stockpiles

Waste rock stockpiles have been used for sludge disposal at other sites. Concepts employed to date include:

- Co-disposal with waste rock during production
- Injection into the waste rock stockpile
- Development of sludge disposal cells on the stockpile flat surfaces.

Co-disposal is only applicable during the operation, when sludge can be spread and buried within the dump. The potential advantages of co-disposal of the sludge include the introduction of alkalinity into the acidic pile and an increase in moisture content, which may reduce oxygen entry into the pile. Injection is similar to co-disposal, in concept. However, sludges pumped as slurries are essentially liquids, which will flow through the dump and report to the toe as seepage flow. Therefore, toe dykes are required to contain the slurry within the pile. The advantage of injection is that the sludge fills the voids and inhibits oxidation. Disadvantages could include remobilization, high costs for the toe dams and dykes, and physical stability concerns. The waste stockpile at Red Dog, being located on a hillside, is likely to be susceptible to stability problems if injected sludge were to saturate the base of the pile.

One promising technique is to dispose of sludge in cells on top of a waste rock stockpile. The sludge cells on the surface act as an oxygen barrier and effectively seal the dump surface to oxygen entry. Construction of the cells is cost effective when the cells replace alternative cover systems such as soil covers or geo-synthetic liners. At closure, the waste rock surfaces will cover an area of more than 250 acres. If cells were built on the waste stockpile that could accommodate 10 feet of sludge, the area could store about 4 million yd^3 and provide about 30 years of storage. Disadvantages of this method are the potential for dust release as the sludge dries and the delay in final reclamation of the waste stockpile surface.

4.3 Pits

Disposal in a closed pit is a common practice. Sludges are pumped into the bottom of the pit. Most deep pits are meromictic (do not mix because of thermal and chemical density gradients) and, therefore, the sludge is effectively isolated from the environment. At Red Dog, there will be two deep pits with a large capacity to store sludge. They are the Main Pit, with a flooded volume of about 22 million yd^3, and the Aqqaluk Pit, with a flooded volume of about 19 million yd^3. These pits would each have the capacity to store sludge for more than 100 years.

The current mine plan calls for the Main Pit to be backfilled with waste rock, but it may also be possible to inject sludge into the backfilled waste. If all of the void space below the water level could be utilized, the backfilled pit could store about 50 years of sludge production.

4.4 Purpose-Built Sludge Management Area

Purpose-built sludge disposal areas are similar to tailings basins. They may be natural basins or purpose-built above ground sludge cells. The primary drawback to these facilities is the need for more land area for the disposal facility. For the Red Dog site, where pits and possibly the waste stockpiles are available for disposal, there would be no advantage to the development of an additional area for sludge disposal.

4.5 Recycling for Metals Recovery

Sludges from mine effluent treatment have been sent to smelters for metals recovery. Teck Cominco has assessed the economics of recycling sludge from WTP#2 with the concentrate from the site. The test work to date has determined this is not economically feasible. After the mine closes, the sludge could no longer be shipped with the concentrate and would have to be shipped separately, making the economics even worse. Therefore, recycling does not appear to be a practicable method for long-term sludge management.

5 Key Findings

1) Sludge production at the Red Dog site is projected to range from about 2,000 to 18,000 t/y. This rate of sludge production could produce an annual volume of as much as 130,000 yd^3.

2) Dewatering options to minimize sludge volumes have been reviewed. The most probable technique for use at Red Dog, should this be required in the future, would be the construction of sludge dewatering beds where freezing would be used to accelerate sludge dewatering.

3) The HDS process at Red Dog will produce sludges that range from 2 to >20% solids by weight. Lower densities may be incurred if source controls are applied to reduce metals concentrations in the untreated waters without a corresponding reduction in flows.

4) Practical repositories for sludge storage in the long term include:
   - The tailings basin, with about 20 years of capacity at a sludge production rate of 130,000 yd^3/yr. Additional capacity could be created by dam raising.
   - The flooded Aqqaluk or Main Pits, each with more than 100 years of storage capacity for sludge at a sludge production rate of 130,000 yd^3/yr.
   - A backfilled Main Pit, with a potential void space capacity that could store about 50 years of sludge at a sludge production rate of 130,000 yd^3/yr.
   - The waste stockpile surface, which could accommodate sludge cells to store about 30 years of sludge at a sludge production rate of 130,000 yd^3/yr.

6 References

Personal communication M. Thompson (May 2004) regarding potential for sludge recycling at Red Dog.

SENES 2004 – Assessment of Water Treatment Methods Applicable for Closure, Red Dog Mine, Alaska. Report to Teck Cominco Alaska Incorporated. October, 2004

SENES 1994 – Acid Mine Drainage-Status of Chemical Treatment and Sludge Management Practices. Report to the Mine Neutral Environmental Drainage (MEND) Program, CANMET. June, 1994.