

Overcoming Active Treatment Challenges

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Abstract The majority of mine sites employ some form of treatment to manage their mine water. However the most successful of treatment operations face some treatment issues. A recent survey of treatment options highlighted numerous challenges that are encountered during treatment. This paper outlines several common and less common treatment issues facing active treatment operations and will discuss options to mitigate problems and improve overall treatment performance. Among the issues to be discussed are: water management, solid-liquid separation, effluent criteria and compliance, low strength waters, scaling, sludge disposal, climatic conditions and operational costs.

Key Words water management, gypsum scaling, sludge disposal, solid-liquid separation, lime, neutralisation.

Introduction

Treatment of industrial waste waters is practiced at most mine sites, whether they are operating or closed. Chemical treatment using lime is typically the preferred method used to remove dissolved metals and neutralise acidity (Aubé and Zinck, 2003). A recent international survey of treatment practices determined that while treatment is a routine process employed at most sites, treatment challenges are common (Zinck and Griffith, 2009). Some of the treatment challenges encountered include water management, solid-liquid separation, effluent criteria and compliance, low strength waters, scaling, sludge disposal, climatic conditions, and operational costs. This paper will briefly discuss these issues and how they can be overcome or minimised.

Water Management

The key to water management at a mine site is to treat only contaminated water and divert clean water. All potentially contaminated waters must be collected and preferably combined to a single treatment system. In some cases, particularly in mountainous areas, costs for water management can be important.

The capital cost of a treatment plant is based primarily on the flowrate. The water management scheme should be designed to handle high flood events – typically a 1:20 or a 1:100 year event. A water treatment plant cannot be economically designed to handle these types of events directly. There is normally a large storage system put in place to handle the events. The size of the treatment plant can be optimised in conjunction with the volume of storage. The volume of water stored prior to spring thaw or wet season should be minimised to allow for sufficient storage space when these events occur.

Solid-Liquid Separation

When treating heavy metals with lime addition, controlling pH and ensuring effective solid-liquid separation is essential. The metals typically treated with lime include Al, Cd, Cu, Co, Fe, Mn, Ni, Pb, and Zn. These metals become insoluble in alkaline conditions. Although the optimal pH setpoint differs for different metals of primary concern, the method of treatment is essentially the same: control pH to the point of lowest solubility to ensure precipitation and allow for the newly-formed solids to decant. This method transfers the deleterious metals from solution to a sludge, thus forming a supernatant water quality that meets the local discharge criteria. In some cases, the pH must be reduced prior to discharge.

The pH control for heavy metal precipitation is a well-known operation that can be easily optimised and maintained. It is a good idea to have duplicate pH probes at control points, but this is a minor cost in comparison to other issues. In typical heavy metal treatment, it is the solid-liquid separation that can be a challenge. As an example, Zn treatment can be used. In Canada, the Zn discharge limit is normally 0.5 mg/L. By controlling pH to 9.5, the resulting dissolved Zn con-

centration is less than 0.1 mg/L. At a mine site where Zn concentrations are the most important in the mine drainage, the formed solids can contain concentrations of 33% Zn. The particles that do not settle, typically have a similar chemistry as the formed sludge. This means that to meet to the 0.5 mg/L effluent limit, the total suspended solids (TSS) from the treatment system must be less than 1.5 mg/L.

This is also an issue when dealing with the treatment of Mo, Se, or As. These contaminants are co-precipitated with Fe to form a solid and must also be separated from solution to meet discharge criteria.

Overcoming the solid-liquid separation challenge starts in the design phase of a treatment system. For pond separation systems, it is necessary to provide sufficient depth, retention time, and minimise wind effects. For a treatment plant with a clarifier, the sizing of a clarifier is critical to the success of a treatment plant. The clarifier is generally sized based on a rise rate, but for a site where the metal concentrations are high, it can be the solids loading that will define the size of the clarifier. In some cases, lamella clarifiers can be used, but these are not conducive to forming a high-density sludge and can be subject to significant scaling problems. Secondary polishing, such as ponds or sand filters, can sometimes be used.

In active treatment systems, a flocculant is used to agglomerate the precipitates and enhance the solid-liquid separation. The choice of flocculant and dosage are critical for efficient separation. Different flocculants should be tried at each separate site as small differences in the water or solids chemistry can affect the optimal choice. Overdosing the flocculant can be as harmful as insufficient dosages. In a system with sludge recirculation, it is also important to ensure that sufficient sludge is regularly purged as the particles can become coated with the flocculant and reduce the separation efficiency.

Effluent Criteria and Compliance

Effluent discharge limits are continually decreasing towards background levels at end-of-pipe. Tighter effluent criteria provide environmental benefits such as reduced contaminant releases and better protection of fish and fish habitat. Meeting such stringent regulations can be challenging and treatment processes need to be modified to meet limits. In some cases, sand filtration may be required to meet the effluent criteria. Some of the key contaminants that require special treatment attention are selenium, molybdenum, arsenic, sulphate, and suspended solids.

Arsenic, selenium, and molybdenum exist in solution as anions, therefore they cannot be treated by simple precipitation as hydroxides. These metalloids can be successfully removed biologically or by membrane systems if concentrations and flowrates are relatively low. In high flow regimes, active treatment involving co-precipitation is necessary. This is typically done by adding ferric iron to the system and co-precipitating with a ferric hydroxide (Aubé and Bernier, 2008; Aubé and Stroiazzo, 2000). In some cases, reduction or oxidation of the metalloid will significantly improve treatment efficiency. In all cases, proper pH control and a sufficient iron addition ratio are key components to meeting effluent criteria.

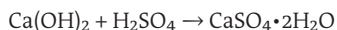
Treating Low Strength Waters

In low strength, low iron systems, precipitates form but cannot agglomerate due to the low population of solids present. The formation of small, isolated particles occurs; which are too few to agglomerate and form larger grains. As such, solid-liquid separation is difficult and compliance exceedances are reported due to total metal concentration rather than dissolved concentrations. In this case, flocculant addition is often ineffective as there are not enough particles present to form agglomerates. To overcome this issue, precipitation mechanisms must be controlled to both minimise nucleation and maximise particle growth. Several options are available to improve the treatment of low strength waters including sludge recycling, ferric ion addition, and precipitation control.

Ferric sulphate or ferric chloride addition can significantly improve metal removal through coagulation, surface adsorption, and co-precipitation. The addition of ferric iron results in the precipitation of ferrihydrite, which is strongly charged and helps to agglomerate other small particles. It also has a strong adsorption capacity which can help to remove some metals remaining in solution. Larger particles are formed by combining with the ferrihydrite and settle much faster than the smaller particles. For Zn, the rate of adsorption varies with temperature and is 3 to 4 orders of magnitude greater at 4°C than 25°C (Trivedi et al., 2004).

Scaling

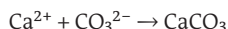
A common by-product of lime neutralisation is gypsum. Gypsum precipitation occurs as mine drainage is often rich in sulphate and the calcium added from lime will bring the solubility product well above saturation. This reaction is often responsible for scaling in treatment processes as well as increasing sludge production at sites where the feed sulphate concentrations can surpass 2500 mg/L.



This scale formation is particularly troublesome for plants where lime is added directly to a raw water that contains significant concentrations of sulphate. Gypsum is a crystal that preferentially forms on existing gypsum. In a high-density treatment system, scaling in reactors is minimised as the gypsum has other surfaces on which to precipitate. When sludge is recycled, there are plenty of gypsum needles available in the slurry and these serve as preferred gypsum formation sites. If a plant operates without a recycle and significant sulphate is present, some precipitation will occur on the reactor wall surfaces. Once these surfaces are coated, gypsum precipitation is facilitated and the rate of precipitation increases. High density sludge (HDS) processes are therefore preferred for high sulphate effluents as they will minimise scaling in the reactors.

As gypsum precipitation is slow, treated effluents often remain supersaturated with respect to gypsum. This can result in scaling issues in upper sections of a clarifier and in the all downstream piping. Preventing gypsum scaling in the effluent system is generally not cost-effective. Once the scale has achieved a certain thickness, it can be cheaper to replace scaled-up effluent piping rather than try to clean it.

Another common by-product of lime neutralisation is calcium carbonate. The inorganic carbon for this reaction can either come from the acidic drainage itself or be a result of carbon dioxide from air, which is dissolved during aeration. This carbon dioxide converts to bicarbonate and then partially to carbonate due to the high pH. The carbonate fraction will precipitate with the high calcium content of the slurry to form calcite (calcium carbonate). This calcite can play an important role in the stability of the final sludge product as it provides neutralising potential to the sludge as it is stored. It is also an indicator of the process lime efficiency: more efficient neutralising processes will produce less calcite.



Calcite scaling is much softer than gypsum and can be cleaned chemically with an acid rinse. It is also possible to have a combination of the two scales together. Metals precipitates and other TSS particles are often combined in these scales in smaller concentrations.

Sludge Disposal

Sludge management is an ever more challenging issue as the volume of sludge continues to increase and the stability of the sludge under various disposal conditions is poorly understood. As such, the management and disposal of these mining wastes requires careful consideration and planning. Issues associated with sludge management include sludge dusting, physical and chemical instability, volume of sludge, and the lack of area for on-land disposal, dredging of sludge ponds, and disposal costs.

Before one can design the most appropriate sludge management strategy for a site, several factors need to be considered. The principle considerations in effective sludge management are the mass of sludge produced, operating or closed mine, dewatering ability of the sludge, sludge density (moisture content), sludge volume, chemical and physical stability, sludge composition, disposal location availability and economics. With the appropriate study and selection of disposal option, if not all, sludge disposal challenges can be avoided.

At an operating site, sludge can be co-deposited with tailings to reduce handling and disposal costs. If there is a tailings backfill, it is possible to incorporate the sludge with this stream. If sludge must be disposed of in a specific cell, it is best to place it upon a sand bed to allow for drainage and increased densification to reduce the long-term volumes. At closed sites (or partially closed sites) a common option is to return sludge to the mine workings. A study of the mine water inter-

actions with sludge can be completed to ensure that this does not increase long-term costs and liabilities.

Climatic Conditions

The most important challenges in cold climates are freezing issues. The metal precipitation reactions essentially occur the same as in warmer waters and the solid-liquid separation is just as efficient. Problems with freezing lines can result in days of downtime when it is necessary to be pumping and treating the water. It is important to properly grade all lines so as to ensure that they are completely drained when pumping stops. If this is not done, a pig should be put through the line at stoppage to remove all water. If the line is to be stopped for an extended period of time over winter, it should be capped at both ends to prevent snow and/or moisture from entering.

Another issue concerning cold-climate sites is the spring thaw. A treatment system must be designed to handle the entire amount of water expected when the snow melts. In permafrost areas, the ground remains frozen during the thaw, which means that all of the melting snow reports immediately as runoff. In these conditions, the water must be stored as the treatment system cannot be economically designed to take this temporary high flowrate.

Operational Costs

Operating costs can be important. The typical range is from approximately \$0.20 to \$1.00 per cubic meter, depending on a number of factors. The most important factors are the raw water characteristics, choice of alkali, the total volume treated, the age of the treatment plant, and the accessibility of the plant. For the choice of alkali, quicklime is most reasonable, with hydrated lime more costly and caustic much more expensive. A higher treated volume reduces overall cost per cubic meter as only one operator is needed and maintenance for larger equipment does not significantly differ. A newer treatment plant is more efficient and requires less maintenance; in fact, after approximately 20 years of operation, it is usually cheaper to build a new plant than to continue with high maintenance costs. As for accessibility, it is much less costly to treat water at an operating mine close to industries and services, than a closed mine in a remote area.

Many of the factors mentioned above are beyond the control of the operator. The factors that can be controlled include: 1) increased automation can reduce labour costs, 2) preventative maintenance can reduce equipment repair and replacement costs, and 3) treatment plant optimisation can reduce reagents and electrical costs. Intermittent operation at full flow rate is another way to reduce costs as operators are only needed at specific times.

Conclusions

Each treatment system has specific challenges and issues. Site specific conditions often make for unique issues and challenges but can also provide opportunities. Common issues include water management, solid-liquid separation, effluent criteria and compliance, low strength waters, scaling, sludge disposal, climatic conditions and operational costs. However with careful planning and treatment know-how many if not all of these challenges can be overcome.

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