Acid Mine Drainage-Background and Solutions – Global Edition

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Abstract

Acid Mine Drainage is a world-wide, growing, environmental problem. Passive treatment systems have been the preferred method to solving this, but the rapid decline in effectiveness of these treatments has given rise to the search for new solutions.

Active treatment solutions have been restricted to chamber filter presses which are labor-intensive to operate and have a high consumable material cost.

Utilizing centrifugation, acid mine drainage treatment systems can take advantage of technology which over the last three decades, has gained familiarity in the mining industry, after decades of established treatment in sewage, gravel washing, drilling mud and solvent extraction applications.

We share some information on this technology, in both how it operates, and its placement in AMD treatment.

Keywords: Centrifugation, Water Recovery, Active Treatment, Mobile Treatment, Solid/Liquid Separation

Introduction

Acid Mine Drainage (AMD) is a global crisis of many names – Mining Influenced Waters, Agua de Laboreo Minera and Acid Rock Drainage to name a few. The formation & movement of highly acid water rich in metals has affected waterways for thousands of years (EPA 2024). With global estimates for resolving this crisis reaching $40 billion USD the attention continues to shift towards technologies which can mitigate and prevent this compounding problem. This paper discusses basic history and technologies surrounding AMD, while providing a forward-looking view towards developing methods for treatment systems.

What is it?

The formula for the creation of Acid Mine Drainage can be classified as the introduction of a sulfide minerals to air and water, which, due to oxidation, results in the orangish/red precipitate containing sulfuric acid and metals such as Al, Mn, Zn, Cu, Pb, and Cd. To put into simple terms, when a portion of earth is exposed to oxygen for the first time, and it encounters water, a chemical reaction takes place, and results in an acidic water, which contains dissolved metals, e.g., pyrite, FeS_2, and an acidic pH level. The exposure of pyrite to oxygen and water can be a natural process, occurring due to weathering in regions such as the Yellowstone Mountains in the United States of America, or in other regions, volcanic activity, although this is not a primary source of the generation of these acid waters. Most frequently, the creation of the acid drainage is a direct result of mining activities, when earth is displaced and exposed to gather ore bodies containing valuable minerals for processing into a concentrate. When this processing area of mining, also known as a disturbed zone, is then exposed to water ingress, in the form of precipitation, stream runoff, and fracture ingress in deep wells, an environment is created which promotes the generation of acid mine waters. This can and does occur at mines which are actively producing, along with mines which have been termed "legacy" due to its inactive status.

Where is it?

While there are multiple regions affected by AMD which are facing an immediate and serious crisis, there are lingering and developing cases of affected waters globally. With tens of thousands of closed mines, thousands of active mines and many hundred in some stage of feasibility, assessment or permitting, the problem is expected to expand.

Particularly critical regions are found in the Appalachian region of the USA, along with the Gauteng Province of South Africa. In the USA, the major source of AMD comes from coal, polymetallic and copper mines. Most of the drainage in this region comes from legacy sites.

In South Africa, a region already facing a water supply shortage, the Gauteng Province has an abundance of legacy mines that once had produced precious metals and coal, now exacerbates the country's critical water shortage. The region estimates 350 million Liters of water affected per day. (Pratt 2012)

Two Major Solutions

Historically, the treatment of acid mine waters when a mine was actively producing ore was not deemed a priority, or in some cases, entirely disregarded. This occurred because the treatment of the waters was not a value-generating stream and generally viewed as a waste product. In legacy mine sites, there was a uniquely different hurdle to face, as the ownership of a closed mine is a liability, which made assigning responsibility for clean-up a challenge often left to the local communities and municipalities.

In recent years, a growing pressure has been applied to the Corporate Social Responsibility targets of active mine producers to provide solutions that mitigate and even reverse the damage created to the environment, while this increased monitoring also encouraged providing local government and communities with funding grants to begin repairing decades of damages when handling their communities' legacy sites.

These methods for addressing AMD can be broken down into two primary categories: Passive Treatment, and Active Treatment. These two methods are uniquely positioned and effective in certain circumstances, which is dependent upon flow rates, time frame, production status, number of affected sites, water quality output requirements and capital/operational funding availability. In both these systems, the primary objective is the neutralization of pH, which then allows for targeted metals to fall out of solution, creating a clear neutralized liquid discharge, and a dewatered solid.

The Passive Treatment system has been the traditional system for treatment, due to its comparatively low capital and operational expenditure for the lifetime of the system. This system operates in a series of ponds, where each pond provides an alteration to the AMD, which brings the affected waters closer to the neutralized metal-free water discharge (Fig. 1). The first set of ponds accomplish the removal of oxygen and the neutralizing of pH via the introduction of a biotic compost and variant of limestone or caustic. The solution is then oxidized in a second set of ponds, which then allow for the metals to precipitate into the final series of ponds, which are often referred to as "sacrificial zones" or polishing wetlands. Ultimately, an outlet of neutral water is produced for further transport or allocation.

The Passive Treatment is responsible for the improvements of water conditions in many regions, although it can face challenges due to its simplistic nature, which may limit the applications for which the system can be deployed. The sacrificial zone can be in defiance of environmental regulation in the region, as it creates a "dead land" which can foster limited flora and fauna, and over time, requires increasingly additional organic matter, limestone and maintenance to slow the increasing decline in water output quality. Because passive systems rely on processes that are slower than conventional treatment, they require longer retention times and larger areas to achieve similar results (Hedin *et al.* 1994). This maintenance is an intense procedure of cleaning out ponds at certain variables to ensure a consistent result, and to allow plenty of depth for static settling.

Transportation of this waste sludge is an expected challenge, especially in regions where the material must be transported via road to final location, as the waste sludge has very slow-solid settling and compaction due to the hygroscopic nature, creating instability due to the water that is retained. With these considerations, the passive system is often best positioned as a solution in closure and post-closure phases for short-term projects.

An Active Treatment System follows the same principles of neutralization, oxidizing and polishing the contaminated liquids, but carries important distinctions in both process and results.

The main distinguishing characteristic of the Active Treatment system is the utilization of a treatment plant, which has operational inputs of chemicals and electrical power. An Active Treatment system is often purpose-built for mines which are in the exploration to operational phases, and for sites in closure and post-closure phases. With centrifugation, this system eliminates the need for settling ponds, allowing for sludge to be stored in stable form, along with opportunities to compact sludge after open-air exposure, making an improved handling/disposal process.

An Active Treatment system generally introduces the acid drainage into a conditioning tank, where it is dosed with

***Figure 1** Construction of a passive system for AMD runoff in Pennsylvania, USA (Image: Stephen L. Benyo).*

a lime slurry, neutralizing the pH. It is then transferred to neutralization reactors, where the material is oxidized, followed by a polymer-supported thickening step, in which the neutralized overflow is free of metal sludge, and the underflow is a thickened neutralized sludge. This method produces a treated water which can meet mandated water-discharge criteria and is often engineered for this specific end-goal. It is a capital-intensive system, but it has potential for cost recovery in its water production, rare earth element collection and solids transport.

Next examples will elaborate on a process developed for Active Treatment Systems, which deploys horizontal decanter centrifugation, to provide additional dewatering of the produced thickened neutralized sludge. With this technology employed, the solids produced from the active system is positioned for effective transportation at 50% dryness, which is effective for loader, conveyor, and truck transport to its next or final destination, while reclaiming additional neutralized water, referred to as centrate when arriving from a centrifuge.

Practical Example of Active System

An excellent example of such an active system (Fig. 2), is available for reference at an active operating mine in the mountainous region of Peru (Fig. 3).

The Active Treatment plant is part of a large polymetallic mine located between 2,200m–3,300m in a semi-dry environment, with an ambient temperature ranging from -5–25°C. The mine has been in operation for ten years, with an additional Life of Mine of 10 years. This location incurs Acid Mine Drainage because of rainwater, which washes out overburden dump creating safety and logistical concerns. 2km away from the mine site, is the processing plant. It is comprised of clarifiers, neutralization tanks, polymer dosing and a 2-phase decanter centrifuge (Fig. 4). Early in 2025, this site is moving from batch to continuous operations, as the anticipated sludge increase requires a 24/7 active treatment to alleviate the environmental effects.

A Flottweg Z4E decanter centrifuge, which

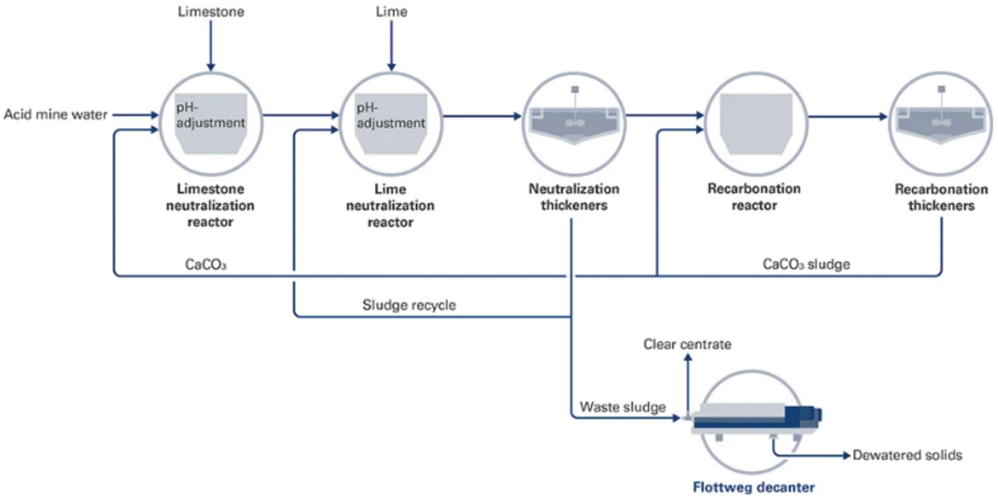

***Figure 2** Active AMD Treatment Plant Flow Diagram (Image: Flottweg SE).*

is designed to handle up to 12m3/h, receives feed from the upstream homogenizing tank, which generally produces a feed containing 3.5% solids by weight.

In start-up testing with the centrifuge, the pulp feed density was calculated at 1.1% g/cc, and the pulp feed solids content, at 1.1% solids by weight. After the feed was processed through the centrifuge, even considering the hygroscopic nature of the material, the solids content improved to 50% solids by weight, allowing for multiple modes of transport and the produced clear centrate retained a 6.9 pH, with minimal residual flocculant and essentially free of suspended solids, suitable for re-use. (Fig. 5).

Mobile Treatment Units or Systems

For AMD-affected regions with multiple legacy sites, or for active mine sites with geographic constraints, an AMD Mobile Treatment Systems serves as a compact solution which is transportable for treatment at multiple locations (Fig. 6). This system maintains key critical advantages of ease of installation, user-friendly and minimal downtime, ensuring continuous and uninterrupted production while maintaining the same levels of efficiency as a stationary system. This can be especially effective in regions which have limited funds, but require treatment at multiple sites, which demonstrate the flexible advantage of mobile treatment. This system is designed as a drop-off flat bed truck platform, which contains a clarifier, polymer dosing unit, mining-configured

***Figure 3** Active AMD Treatment Plant in Mountainous Region of Peru (Image: Emerson Huayanca).*

***Figure 4** 2-phase centrifuge processing neutralized waste sludge (Image: Jimmy Cordova).*

Figure 5 Solids discharge and centrate quality from decanter centrifuge.

centrifuge, and other ancillary equipment such as pumps, sensors and control panels.

Conclusions

The use of centrifuges for neutral sludge dewatering is a viable, effective, and economical alternative to existing technologies. When considering the environmental impact, space requirements, costs and increasing future demands, mechanical separation of solids and liquids by centrifugal force will increasingly find its way into modern mining and sludge treatment operations.

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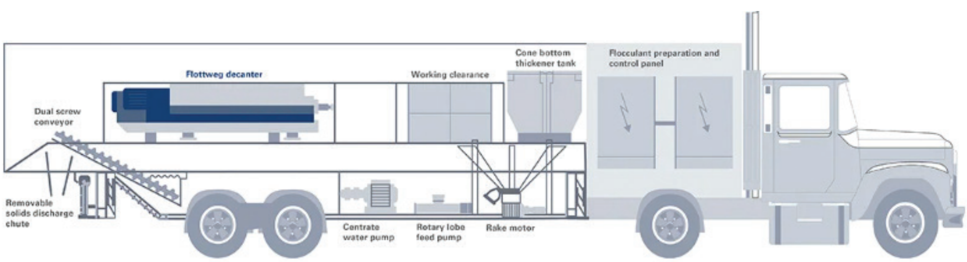

Figure 6 AMD Mobile Treatment System.