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MANAGEMENT OF ACIDIC EFFLUENTS FROM TAILING DAMS IN METALLIFEROUS MINES

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ABSTRACT

Mining activity is one of the many causes of pollution of water resources and creates a condition of imbalance between the land and water regime, in both quantitative and qualitative manners. Among the various causes of qualitative pollution, acid mine drainage (AMD) is more predominant and is produced in mines when pyrite and other sulphide minerals become exposed to the atmosphere. The very nature of mineral processing practices such as milling and grinding which are designed to maximize metal recovery also maximize the exposure of the surface area mine tailings and waste materials to subsequent oxidative processes. Though 3.6x 10^8 Sq. km area out of total 5.6x 10^8 Sq. km area of the earth surface is covered by water, yet it is surprising that only 0.3 percent of total available water is fit for human consumption and there is scarcity of potable water. The rapid industrialization and consequent rapid urbanization is exacerbating this potable water scarcity. By keeping this in mind the current paper discusses merits and demerits of various existing methods to manage or control acid generation due to sulphide minerals in tailing dams in order to utilize dam water for further uses.

INTRODUCTION

AMD is one of the most severe problems produced as a result of exposure of sulphide minerals during mining and mineral processing activities. Acidic drainage is not exclusively limited to mining operations: it can happen wherever sulphide minerals are exposed to oxygen and water [1, 2, 6]. Carbon dioxide and soluble chemical species are also reported to enhance the mineral dissolution [11]. To some extent, climatic conditions also play important role, particularly temperature, rainfall and wind velocity. However, the very nature of mineral processing practices such as milling and grinding which are designed to maximize metal recovery, also ensure, maximum surface area exposure of mill tailings and waste materials to subsequent oxidative processes. While the presence of sulphide bearing minerals is a necessary condition for the generation of the acidic drainage, it is not a sufficient condition in itself, for there will not be any AMD if the sulphide are non reactive, or if there is a sufficient quantity of alkaline minerals present in rock associated with coal/ore to act as buffering minerals [6, 11].

The following parameters determine the rate of oxidation and acid generation [1, 5, 6, 11, 12].

- Degree of saturation
- Oxygen concentration
- Temperature
- Size distribution
- Types of sulphide
- Solution pH
- Solution Eh
- Concentration of sulphide
- Presence of certain bacteria

AMD occurs when the following conditions are met [6]:

- Waste material contains enough sulphide minerals to react and create acid leachate at a faster rate than it can be neutralized by any surrounding alkaline minerals.

- There is sufficient water and air infiltrating into the waste material to support the chemical and biological reactions.

- The presence of surface water that infiltrates and transports the acidic drainage into the environment.

The following are the environmental problems of a serious nature normally associated with acid mine water drainage besides corroding mining machinery and pumps:

(a) Ground water contamination due to infiltration of this acid water into surrounding aquifers and henceforth recharging in wells thus spoiling potable water.

(b) Spilling of this water in local rivers , thus disturbing the fragile ecosystem of the water and hence threatening aquatic life and posing health hazards to men and animals.

The problem is further aggravated with the high percentage of sulphide minerals in the form of waste being disposed off into impoundment during metallic mineral beneficiation processes.

TREATMENT TECHNIQUES FOR AMD

The methods of dealing with such drainage ranges from the addition of lime, to engineered wetlands and even reverse osmosis [1, 3, 14]. Depending upon the location of tailings dams, nature of AMD, socio-economic conditions of the

Table 1 Comparative statement for various treatment techniques applied to acid mine drainage

Technique	Merits	Demerits
1. Lime treatment	Simple method effectively precipitates heavy metals	1 Precipitates heavy metals in absence of complex compounds 2. Cyanide or molybdenum can not be removed 3. Costly method in terms of material, handling and disposal costs. 4. Limestone coated with insoluble products becomes inactive. 5. Sludge creates a variety of environmental problems. 6. Does not produce long term solution
2. Lime substitution **(Neutrafix and nutriment)**	1. Cost one half of the lime treatment. 2. Faster settling rate and compact sludge in comparison to lime treatment. 3. Smaller quantity needed.	1. Slower neutralization rate 2. Commercial availability of the product may be detrimental factor.
3. Industrial minerals	1. Natural zeolites, vermiculites and fuller's earth, kieselguhr, dolomite and sandstone 2. Large quantity of local supply of minerals necessary.	1. Particle size of minerals affects the permeability. 2 Change in mineral grade affects the treatment methodology and results.
4. Under water disposal	1. Prevent contact with oxygen., thus limiting acid generation. 2 Effect can be augmented with thin layer of oil	1. Effective below certain depth of water. 2. Oily substance sprayed should not hinder with mineral processing.
5 Bactericides	1. Biodegradable anionic detergents at low pH. 2. Cow manure or decomposed wood chip also effective.	1 Effectiveness limited by rainfall events. 2. Cow manure or wood chips increase the turbidity of water. 3 Heavy metal precipitation capacity is not yet established.
6. Engineered wetland	1. Environmentally friendly method 2. Cheap, cost effective and minimum supervision	1. Adequate land area required. 2. Efficacy depends upon sufficient water cover. 3 Evapotranspiration in warmer countries lowers the efficiency of metal removal. 4 Sulphate reduction reaction may limit wetland operational life.

surrounding area and environmental constrains in the area, suitable methods are being adopted for treatment and management of AMD in tailings. The comparative study of existing techniques for AMD management in tailings is shown in Table 1. Two fundamental approaches may be adopted to prevent any environmental damage [1]:

(i) removal of contaminants (in situ), or
(ii) modifying the local environment (in situ).

The above two approaches can be applied in either of the following two methods in the case of AMD management: (i) passive treatment, no electrical energy is required at the site.(ii) active treatment, electrical energy required at the site.

A common solution applied to acidic drainage problems is treatment with lime or other neutralizing chemicals [1, 2, 4, 5, 9, 13, 15]. AMD is treated with lime and metals in solutions are precipitated as metal hydroxides and the sulphate as calcium sulphate. The precipitated slurry is then aerated to convert ferrous iron into ferric iron, which is more stable, for storage and disposal. The precipitate is next flocculated with a polymer flocculant and settled in the thickener to produce a sulphate/hydroxide sludge and a final effluent discharged into the environment. The whole process is shown schematically in Figure 1.

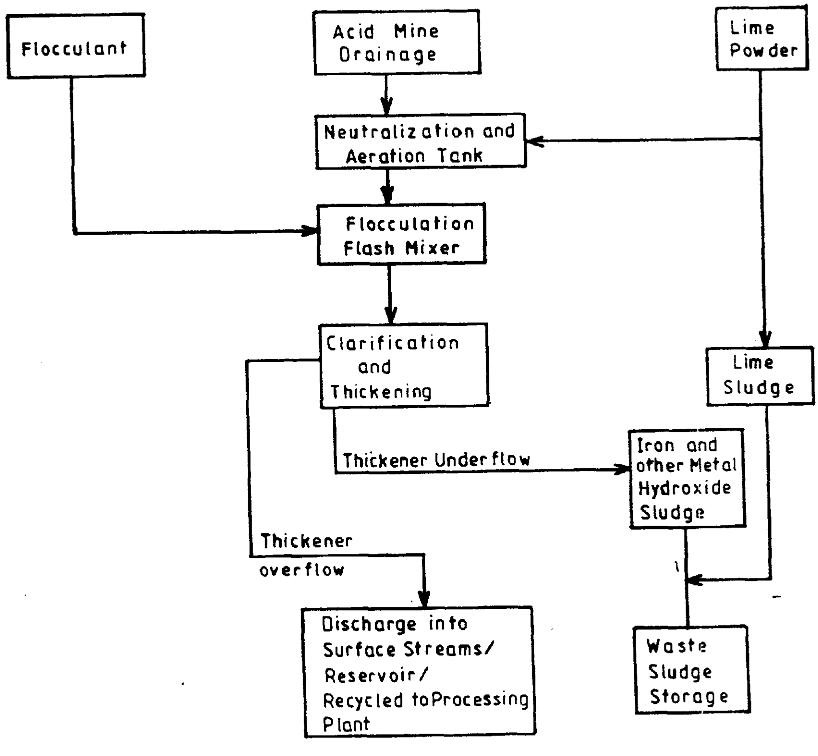

Figure 1. Block diagram for acid mine drainage treatment with lime

Lime treatment is a cost intensive method because of the chemicals cost , labour involvement, handling/ disposal of the process residues and also does not always present long term solutions. The limestone may quickly become coated with insoluble reaction products which impairs its ability to neutralize the water. The metal hydroxide sludge produced by the process requires landfill disposal. The sludge might, under certain circumstances, be considered hazardous waste and require special additional treatment and/or disposal provisions [2, 15].

Neutra-Fix and Neutra-Ment, waste byproducts produced by a new crude oil combustion and gasification process at Ashland Oil Co. in Catlettsburg (Kentucky), has reported as a lime substitute for the treatment of AMD [9]. These are effective, and the cost is less than half that of lime. Chemical analysis of the Neutral products suggest that they are Dolomite material [9] . They produce sludge that is more compact than those from lime and the sludge settling rate is also faster than the lime. Although rate of neutralization is slower a smaller quantity of Neutral products may be required to neutralize and precipitate AMD than lime [9] .

Industrial minerals are also the subject of experiments due to their capacity to control the generation of, or buffer, acidity, reduce concentration of potentially phytotoxic elements in solution and to act as slow release agents for macroneutrients through ion-exchange [1, 10]. The minerals chosen by Atkinson (1994) can be split into three types, viz., natural zeolites (clinoptilolite and modernite), layer lattice minerals (vermiculite and fuller's earth) and biogenic silica (Kieselguhr).The results from their work indicate that in terms of the laboratory and columns tests, Clinptilolite as well as Kieselguhr, have been the most suitable for amending land contaminated by metalliferous mining. In practical field tests it has been found that although Kieselguhr is satisfactory and reproduces the characteristics indicated by laboratory test work, it is unsatisfactory because of its negative effect on permeability. Vermiculite and natural Zeolites both perform well under field conditions, and the various particle sizes of the vermiculite also mean that it can he used to improve the particle size distribution of the soil and therefore, improve the permeability and drainage [1]. Jamal et al. (1991), showed the potential application of sandstone for AMD abatement through their experiments on acid water collected from coal fields. Though results are encouraging, they did not extend their work to metal mining and in field situations.

It is believed that covering of waste rock and tailings sites with water will minimize the transport of oxygen and therefore limit, or even totally prevent acid generation [5.8]. The effectiveness of this method can be augmented if a thin layer of oily substance can be sprayed and maintained on the water surface [8]. This may be an effective solution only if a certain minimum height of water is always maintained [5, 8]. If a layer of oily substance is sprayed, it should not hinder further mineral processing.

Bactericides have also been used to reduce the micro biological activity associated with sulphide oxidation and the formation of acidic drainage [4.12] . The anionic detergents are the most economical inhibitors of T. Ferrooxidans [12]. Normally considered as cleansers rather than bactericides, anionic detergents do have bacterial properties at low pH (Chadalau, 1968), are readily available in biodegradable forms and are environmentally safe at low concentrations. Concentrations above 10 ppm slow acid production while concentrations of at least 25 ppm reduce acidity levels to that of sterile controls by killing the bacteria (Kleinmann and Crerar, 1979) . However, simple application of anionic detergents would be effective only until the next major rainfall due to their high solubility. The Lilly and Orphan Boy mines near Ellison, Montana (USA) reported to using cow manure and wood chips as a sulphide reducing bacteria to control AMD (Heunish, 1987).

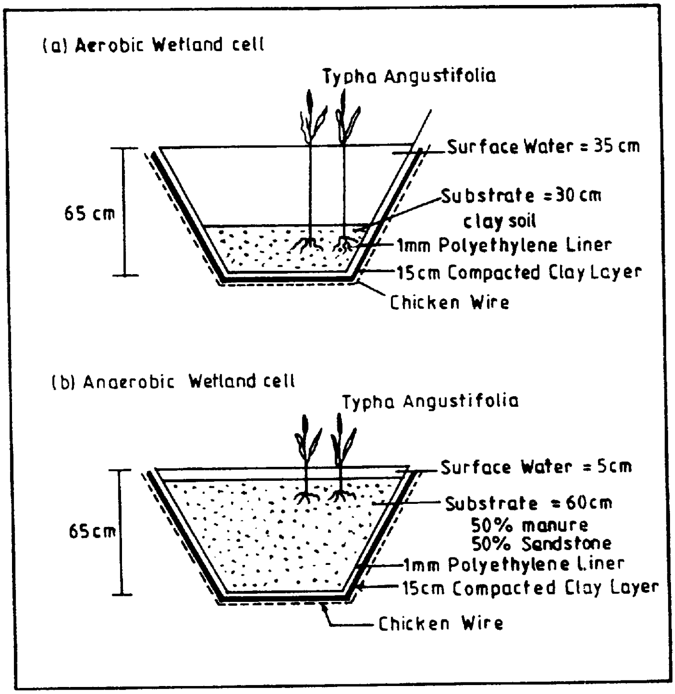

Figure 2 Typical design of aerobic and anaerobic wetland cells (Donahue, 1994)

Researchers have found that wetlands have a certain capacity to remove metals and improve water quality [3, 4, 5, 14]. The technology has also been applied to metal mine drainage with demonstrated improvements in water quality (Michaud 1994). This methodology offers advantages over chemical neutralization as large volumes of sludge are not generated as metals may be precipitated as oxides or sulphide in the wetland substrate [3.14]. The key goal of constructed wetlands is the long term immobilization of metals. Several physical, chemical and biological mechanisms are known to operate within the wetlands which reduce the metal concentrations and neutralize the acidity of incoming streams. Notable mechanisms include [3, 14]:

- filtration of the suspended material,
- metal uptake into live roots and leaves,
- ammonia generated neutralization and precipitation,
- adsorption and exchange with plant, soil and other biological materials,
- hydroxide precipitation catalyzed by bacteria in anaerobic zones,

- sulphide precipitation catalyzed by bacteria in aerobic zones.

There are aerobic and anaerobic constructed wetlands [14]. Aerobic systems consist of wetland of more diverse vegetation growing in a clay soil or mine spoil substrate. Anaerobic wetlands are constructed with a thicker organic substrate composed of organic materials such as hay, manure, peat moss, or mushroom compost. A typical design of both the systems is shown in Figure 2. Besides the aforementioned techniques reverse-osmosis, ion-exchange, electrolysis, elector-oxidation and reduction, activated carbon sorption method, etc. may be used for removing the dissolved as well as colloidal organic and inorganic compounds [15]. These methods are more expensive but may be used to produce sufficient control.

DESIGNING A NEW TREATMENT SYSTEM

The term amendment is used generically for materials added to contaminated land, as it is felt that this term describes the spoil modifying nature of the added material. Extensive laboratory studies to characterize amendments have to be undertaken to establish a variety of characteristics, including the following :

- Theoretical cation exchange capacity (CEC)
- Acid neutralization capacity
- Cation exchange characteristics from ideal metal sulphide solutions
- Stability in acid media
- Thermal stability (freezing -thawing)

CONCLUSIONS AND SUGGESTIONS

It may be concluded from the above discussion that there is not a single method for treatment of acid effluent of tailing dams which can solve the problem on long term basis and applicable and acceptable universally. There is a strong need to carry more research towards solving the problem so that human developmental activities may go on incessantly without spoiling the environment. Authors are of view that in applying and developing new amendments to contaminated land it is important to emphasize that:

- no specialized equipment is required,
- disturbance of the land is minimized so as not to expose any remaining sulphide minerals at a depth to oxidation,
- sludge formed should be settled down quickly as solid rather than forming a colloidal mixture,
- amendments should not have any negative effect on permeability and drainage,
- amelioration scheme should not be such that the removal of one problem poses another environmental threat,
- quantity of amendment required should be minimised,
- solution should be long term based, and
- above all, techniques should be economical .

It is also suggested that at the time of experimenting with a new amendment, interaction of acid water with different rocks in and around the mining area should be given the highest priority. A study undertaken by the authors, currently in progress, shows very promising initial results on such acid consuming rocks.

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