

TREATMENT TECHNIQUES OF THE ACID MINE WATER USING THE SUCCESSIVE ALKALINITY PRODUCING SYSTEM

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Abstract: Mining practices cause environmental problems, affects human health and damages the ecosystem. It disturbs geo-formations which take millions of years to form. It also affects the natural process like hydrology. Due to mining activities, different types of problems may arise from direct physical hazard to pollution of water and soil. Acid mine drainage (AMD) which refers to polluted, typically acidic mine water formed from oxidation of predominant traces of sulphide ores from mining exposures, which at later stage undergoes Chemical reactions under atmospheric condition Successive Alkalinity Producing System (SAPS) are most efficient technique to treat AMD water. The main principle behind this is the combination of both anaerobic wetland and ALD. The SAPS uses the benefit of vertical flow of influent also called as vertical flow wetlands. The SAPS like anaerobic wetlands that are constructed on top of limestone drainage beds. Mine wastewater flows vertically through organic matter and limestone layer which adds the alkalinity to influent.

Keywords: Acid Mine Drainage (AMD), Active treatment, Passive treatment

1. INTRODUCTION

Acid Mine Drainage is a major pollutant in the mining areas of the world attracting attention of Environmental Engineers. In the presence of water and oxygen, oxidative decomposition of sulphide minerals mainly pyrite, FeS₂ gives this acidic, metal filled water. The high acidity of mine water and large amounts of dissolved heavy metals, such as like copper, zinc, manganese, iron, arsenic, lead etc. It is generally make AMD very toxic for most organisms.

Mining activities highlight a significant amount of pyrite mineral deposited in layers of rock beneath the surface of the earth. Mining activities bring these deposits to the surface where they are crushed to leave precious minerals like copper, zinc, gold, nickel etc. The pyrite comes in contact with surface conditions like air and water which will help in the oxidations of pyrite for the production of AMD (Jenkins et al., 2000). Due to abundance in the environment pyrite mineral is recognized as the major source of AMD (Evangelou, 1998).

The nature of Acid mine water contamination is very different from one site to another because its formation is dependent on various factors. AMD often contaminate water quality and inhibits aquatic life and is often characterized by one or more of the major components:

- i. Low pH is high acidity like Acid Mine Drainage (AMD)
- ii. High metal concentrations like iron are the most common metal.
- iii. Sulphate concentration.
- iv. Excessive suspended solids

Acid is a major problem in streams because this can corrode metal pipes and structures, break concrete, and kill plants, micro organism other aquatic life forms. Water runoff of acidic surface can also break the metal compounds of iron, Sulphur, manganese and aluminum found in nearby cliffs and mud waste piles.

2. LITERATURE REVIEW

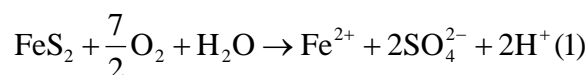
Acid mine drainage is an Environmental pollution associated with the mining industry. The problem of AMD has been associated with mining industry ever since mining began. The main reason of occurring of AMD is the occurrence of pyrite and sulphide minerals in the rock. Water seeping and percolating through the cracks and faults of the strata when comes in contact with the rocks and minerals generates AMD (R.W. Gaikwad et al, 2007).

AMD residues have low concentrations of pH and high concentrations of iron, aluminum, manganese and toxic heavy metals etc. The amount of AMD produced is dependent on the size of the surface area of the present sulphide minerals. The concentration of ions of dissolved metals also depends on quantity and type of sulphide minerals (Ata Akcil et al, 2005)

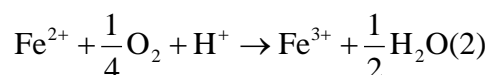
Limestone, the least costly alkaline agents, would supplant the more expensive alkaline agents in common use for neutralization. Aeration after neutralization would be eliminated. The dense, small volume of sludge produced at near neutral pH conditions would significantly reduce the cost of sludge separation and handling (Mihok, 2011).

Chemistry of Acid Mine Water:

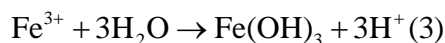
The first step oxidation of iron sulphide like pyrite is the primary mechanism by which acid is released into mine drainage. The process is initiated by breakdown of the pyrite in the presence of oxygen and water to yield ferrous ion, sulphate and acidity.



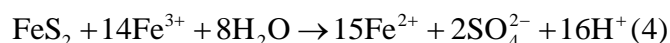
The second step when the sufficient oxygen is dissolved in water, the oxidation of ferrous to ferric iron occurs in the next step. This reaction is greatly accelerated by a species of bacteria thiobacillus ferrooxidans.



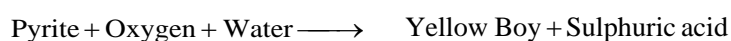
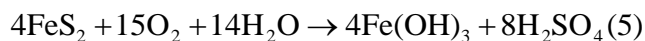
The third step involves hydrolysis of ferric iron to produce the solid ferric hydroxide and the release of additional acidity. This step is pH dependent.



The acidity increases, the reaction reinitiates because ferric iron remains in solution and is reduced by pyrite, resulting in the release of ferrous iron and acidity.



The final step cyclic of acid generation by ferric iron takes place very rapidly and continues until the supply of ferric iron of pyrite is exhausted. The overall sequence of reaction is acid producing ferric hydroxide is called Yellow Boy.



3. METHODOLOGY

Successive Alkalinity Producing System (SAPS):

(a) Introduction: Coal mine drainage may be described as net acidic or net alkaline. Ferrous iron (Fe^{2+}) is most common and abundant contaminant in coalmine drainage. The oxidation and hydrolysis of Fe^{2+} is largely considered as having more contribution in acidity, thus it termed as acid mine drainage. Net alkaline considered as having satisfactory neutralization potential like bicarbonates (HCO_3^-), which accepts any proton generated by above reactions. Manganese and aluminum also increases acidity and required to consider in balancing of acidic vs. alkaline discharge.

The uses of passive system are increasing now. Net acidic water having less amount of ferric ion, aluminum and dissolved oxygen can be neutralize by ALDs but causing clogging of pores and armouring of limestone. To solve all the problems SAPS are developed having vertical flow tendency. The System having limestone layer and organic layer is provided with settling pond. Limestone layer increases alkalinity and organic layer decreases dissolved oxygen, aluminum and also reduces ferric ion to ferrous. System having 10 times more tendency to generate alkalinity.

(b) Principle: The principle behind this is use of combined benefits of ALD and anaerobic wetlands. Now the terms used for this system is vertical flow reactors due to vertical fall of influent water. SAPS are designed to deal with dissolved oxygen content between 2 mg/L to 5 mg/L and also for medium to high metal concentration. The vertical flow increases with contact time. When the entering limestone it adds alkalinity again lowers the dissolved oxygen then further increases alkalinity. Flushing is provided to remove metal concentrations to avoid clogging.

SAPS can treatment of mine water the following criteria:

- i. Net acidic can generally treat maximum acidity levels ranging from 300- 500 mg/L
- ii. Moderate to high levels of ferric and ferrous iron greater than 0.25 mg/L, aluminum and dissolved oxygen greater than 5 mg/L.
- iii. Influent Flow rates low to moderate used depend upon SAPS size and capacity.

(c) Methodology: It composed basically three units, which is SAPS unit, oxidation and sedimentation units followed by wetlands.

Successive alkalinity producing system: It consist cylindrical anaerobic column which is filled with a layer of limestone gravel, a layer of organic substrate and above portion filled with AMD water.

Oxidation chambers: Here the SAPS effluent allows metal oxide to precipitate and maintains anaerobic environment. Efficiency of organic substrate not eventually decreased because of avoiding ochre deposits inside wetlands.

Wetland: Water enters into wetland from last oxidation pond, the whole wetland divided in 15 sections and water flows in circular path. Bottom is filled with bentonite, which is impermeable clay having ion exchange capacity. The rest of wetland is filled with limestone. And sufficient bio plants like typha.

(d) SAPS Design: Net acidic mine water containing high concentration of ferric iron and aluminum (> 3 mg/L), get neutralize with SAPS or series of SAPS. Passive system generally consist main components like anaerobic wetland, oxidation and settling pond (Patel et al. 2018).

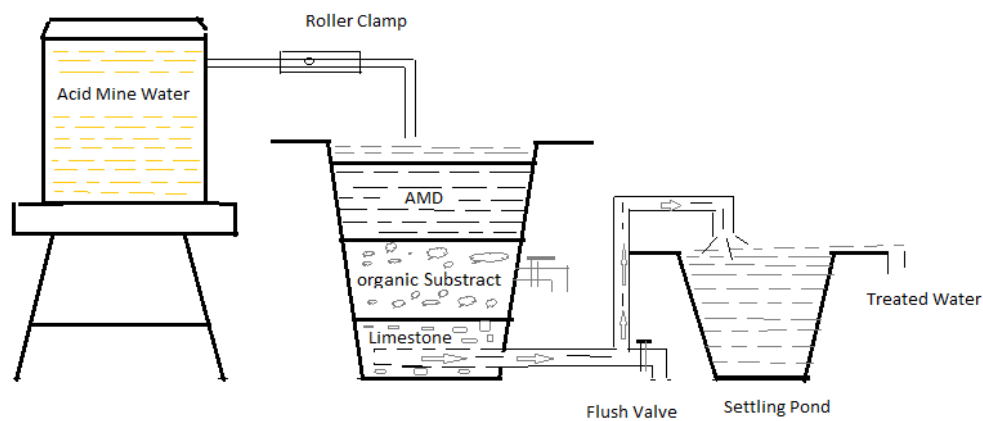


Fig. 1: Laboratory setup for Treatment of Acid Mine water through Successive Alkalinity Producing System

Hydraulic Retention Time: The HRT is measure of average length of time that a soluble compound remains in the constructed SAPS. The volume of aeration tank divided by influent flow rate is hydraulic retention time.

Effects of HRT on efficiency of SAPS have been widely studied and it is usually considered that precipitation of metal sulphides occurs in 3 to 5 days (URS report 2003). A shorter HRT does not provide adequate time for SRB activity to neutralize acidity, whereas longer the HRT having tendency to deplete organic matter source (Devorak et al. 1992).

For designing of SAPS system different parameters like increase in net alkalinity and HRT are used. The relation between net added alkalinity to retention time shows positive correlation. The value of correlation coefficient is almost 0.46, significant at the 1% level, through appreciable scatter exists. These data shows that very long retention time could be beneficial for some water.

Increased HRT shows a larger volume (mass) of limestone at given rate of flow. But this parameter is not considered as primary criteria of design.

Laboratory Work and Analysis:

As said earlier on the basis of constructed SAPS, allow the AMD water to pass through SAPS unit with different flow rate. The flow rates are like 40 ml/minute, 20 ml/minute, 12 ml/minute, 8 ml/minute and 4 ml/minute. When water passes from SAPS tank and from first oxidation cell, sample is taken as P₁ & P₂. P₁ is the water sample taken from overflow of SAPS tank and P₂ is the sample taken from overflow of first oxidation cell. For each flow rate two samples are taken as P₁ and P₂, total 10 samples and 1 AMD water sample is collected in lab. The flow rate of 4 ml/minute has the highest HRT and for 40 ml/minute the HRT is lowest.

Retention time is calculated in hours, when total volumes of influent remain in the SAPS is divided by the provided flow rate at that time.

Table 1: Measurements of HRT using different rate of flow of influent

| S. No. | Volume of influent in SAPS (L) | Flow rate (ml / minute) | HRT (hours) |
|--------|--------------------------------|-------------------------|-------------|
| 1. | 20.37 | 40 | 8.50 |
| 2. | 20.37 | 20 | 17.00 |
| 3. | 20.37 | 12 | 28.30 |
| 4. | 20.37 | 8 | 42.40 |
| 5. | 20.37 | 4 | 84.00 |

Analysis for pH, EC & DO: The measurement of pH, electrical conductivity and dissolved oxygen is done in Environment Engineering Lab. Direct digital data is taken for different samples using pH meter, water conductivity meter and dissolved oxygen meter respectively. Taken the sample in the biker and dip bottom side into the sample, one by one different meters are used to get pH value, electrical conductivity and dissolved oxygen.

Observation:

Table 2: Observed reading of pH, DO & electrical conductivity (EC)

For sample: pH = 6.8, DO = 5.8 mg / L

| Flow rate (ml / minute) | P ₁ | | | P ₂ | | |
|-------------------------|----------------|------|------|----------------|------|------|
| | pH | EC | DO | pH | EC | DO |
| 40 | 6.84 | 1283 | 0.05 | 6.90 | 1412 | 0.05 |
| 20 | 6.90 | 1209 | 0.04 | 6.92 | 1300 | 0.04 |
| 12 | 6.91 | 1070 | 0.03 | 6.94 | 1240 | 0.03 |
| 8 | 6.94 | 1056 | 0.02 | 6.98 | 1212 | 0.02 |
| 4 | 7.10 | 1031 | 0.01 | 7.37 | 1121 | 0.01 |

- pH increases as increase in the HRT; as we can see the observation table with different flow rates and their respective pH of solution. pH and HRT always showing linear relation.
- DO levels observe in lab means to zero always showing the favorable condition for anaerobic reduction of metals
- Electrical conductivity showing the free metal ions in the solution; as increase in HRT the electrical conductivity gradually decreasing. Result showing the precipitation of metals and subsequent metal removal at oxidation pond.

4. RESULT

pH and HRT: Under different flow rate of influent, the calculated HRT and observed pH always shows positive relation. As we decrease the flow rate, HRT will increase simultaneously pH increases from 6.9 to 7.37. Increase in HRT allows sulphate reducing bacteria (SRB) to increase the alkalinity of influent as higher HRT provides enough time to SRB to neutralize the acidic water.

- For the flow rate of 40 ml/min with pH increases up to 6.90 having is retention time of 8 hours almost.
- For 20 ml/min flow rate pH increases up to 6.92 retention times of 17 hours.
- For 12 ml/min flow rate pH increases up to 6.94 having retention time of 28 hours.
- For very low flow rate of 8 ml/min and 4 ml/min pH of influent increases up to 7.37 having is residence time of 3.5 days.

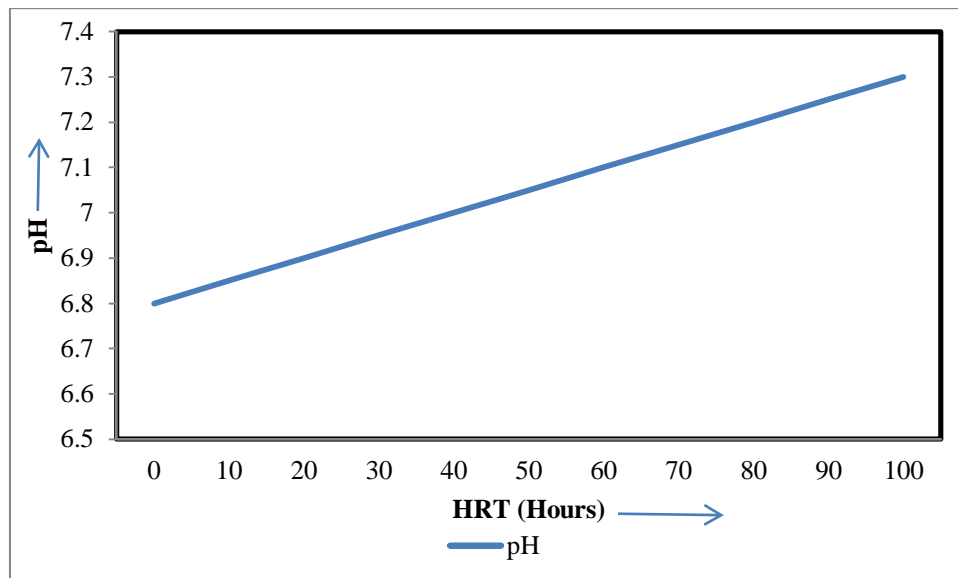


Fig. 2: Graph between pH and HRT

EC and HRT: EC shows the amount of free ions in the influent. As increase in retention time, it allows the metal ions to precipitate and as the metal ion precipitates the alkalinity of influent increases. As number of settling pond we increase with SAPS tank we get precipitated metals respectively.

Iron precipitates in the form of iron sulfide and ferric hydroxide; generally iron precipitates above the pH of 3.5. Aluminum precipitates between the pH of 5 to 8 in the form of aluminum hydroxide. Mn precipitates at pH of above 10.

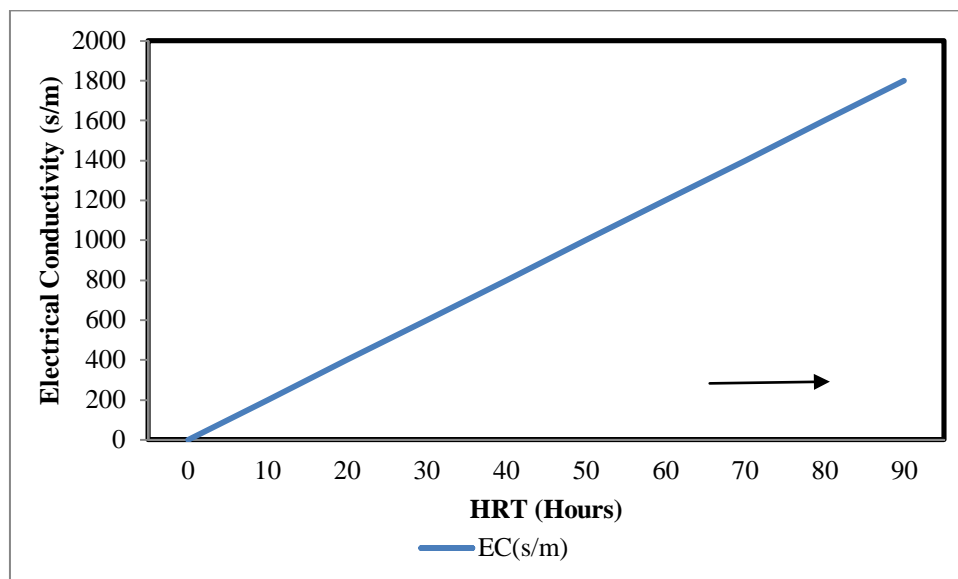


Fig. 3: Graph between Electrical Conductivity (EC) and HRT

5. CONCLUSION

- It is found that alkalinity generation increases with increase in duration of HRT.
- It is also found that the EC is getting reduced with too longer HRT because EC is inversely proportional to HRT. Hence significant metal removal had taken place.
- The DO levels in SAPS during experiment were observed mean to zero which shows a favorable condition for anaerobic reduction of metals.
- Presently SAPS system has been found very effective in treating highly acidic and high metal (like Fe, Al and Mn) containing AMD.
- SAPS having benefit of both active and passive system with long life, limited area needed, efficient and less armouring of limestone.

- This method used not only for treatment of AMD but also used for metal removal.

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