TECHNOLOGIES FOR EFFECTIVE TREATMENT OF ACID MINE DRAINAGE

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Abstract
Acid mine drainage has severe environmental effects. These environmental effects can be injurious for living organism. Acid mine drainage influence water quality, destroy the plant, human health, animals life, corrosion of pipes, building and construction materials, Increasing degradation and contamination of aquatic resources and make water quality harmful for human and biota consumption. Presently treatment and management of mine influence water due to its persistent nature have significant challenges for people, NGOs, miners, and researchers globally. The generation of acid mine drainage once initiated, can continue for a very long time after active mining operations have ceased. Traditionally available treatment methods are not suitable for acid mine drainage treatment. Now a day's passive treatment system has been proposed by many researchers as low-cost, effective option and implemented by many develop and developing the country for the management of acid mine drainage. This review paper summarizes the applications of an active and passive treatment system for the treatment of acid mine drainages.

Index Terms: Acid mine drainage, effect, active and passive treatment system.

I. INTRODUCTION

The coal and minerals mines discharge solids and liquid waste during different mining activity. The liquid waste is known as acid drainage (AD) or acid mine drainage (AMD) or also called acid rock drainage (ARD). Acid drainage has high acidity, turbidity, low pH content, high contents of dissolved heavy metals [1-3], and iron [4]. All coal and minerals mining operation produced much toxic waste. This is harmful to the air, water, soil, and biodiversity [5-6] including severe health risk to human [7-8] animals and vegetations. Its serious environmental effects also transfer from generation to generation [9-10]. Thus, efficient and economical treatment technologies are required for reducing the harmful impacts of AMD [11] from the natural environment. To manage the acidic water in mines, typically two types of treatment system used known as active and passive treatment, meaning on the addition of alkaline chemicals to neutralize the acidity or passive treatment system, means trust on biological, geochemical, and gravitational processes [3]. The active treatment system is used to reduce acidity and metals from acid mine drainage an expensive alternative for the long-term liability. In the present times, many passive treatments have been developed by many researchers for the treatment of acidic water, without using harmful chemicals and that take benefit of naturally available resources to cleanse the contaminated effluent generated from coal and minerals mines. The first passive treatment system also incorporated anoxic limestone drains (ALD), constructed wetlands, limestone ponds, and open limestone channels (OLC), successive alkalinity producing systems (SAPS). The Passive treatment does not involve regular maintenance, chemical reagents or energy.

II.SOURCES OF MINE INFLUENCE WATER

The usual sources of mines impact water during different mining activities are runoff from open pit workings, Infiltration of rainwater into waste rock dumps piles, milling area, haulage roadways, contaminated surface [3,12]. Infiltration of groundwater onto waste rock dumps piles, Spent ores piles, upon inactive of mines sites, this is usually followed by flooding, Active and inactive tailings lagoons [13].

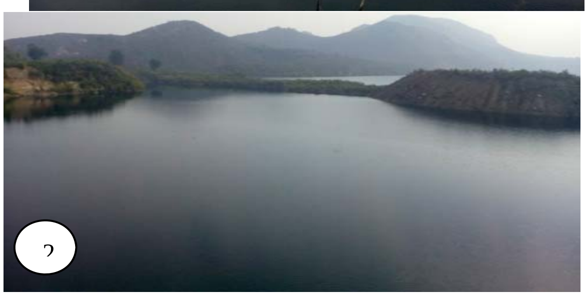


Figure 1 and 2.Acid mine drainage from an abandoned coal mine has shown in picture situated in Singrauli area India, having very low pH and high concentration of Iron.

III.TREATMENT OF ACID MINE DRAINAGE

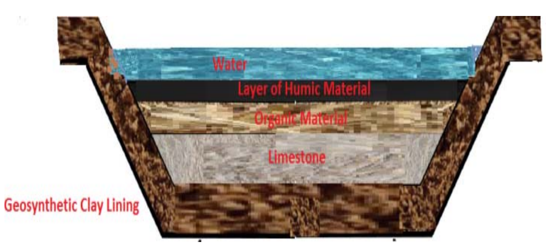
Treatment of (AMD) is broad categories, in active and passive treatment. An active process is very complicated, required higher operation costs and additional unit operations as compared to the easiest and simple passive system. The passive system required very less operating and maintenance cost as compared to the active treatment process. Many methods are used in develop and developing countries all over the world for the treatment of acid mine drainage. These treatment methods are adsorption [14-18], biosorption [19], electrochemical remediation [20], ion exchange [21], neutralization [22], oxidation and hydrolysis process [23], precipitation [24], titration [25]. All these processes are used for removal of pollutant from wastewater; out of the above treatment, process adsorption offers an additional benefit regarding treatment efficiency, economical and simplicity in operation [3, 16] and maintenance..

Active Treatments

Active treatment systems are used for the enhancement of water quality [26]. It's required bio-Chemical reagents or artificial energy for neutralization of AMD [27]. There are numerous studies carried out on the variations of this treatment processes by numerous of researchers, but ultimately this process involves the addition of base to neutralize acid [28-29].In active treatment system, Calcium Oxide, Calcium Carbonate, Calcium Hydroxide, Ammonia, Sodium Hydroxide and Sodium Carbonate are used in the neutralization of AMD [3, 28], agricultural limestone and phosphate rocks have also been used to treat AMD [30] as liming materials. This process neutralizes the AMD and precipitates the metals ions from the solution at different pH level. However, this system needs a regular and continual commitment to treatment, the breakdown of machinery/equipment, different climate situation, and small funds can decrease the treatment efficiency.

Passive Treatments

Many rules and regulation have been given by many national and international organization for sustain the health and quality of the natural environment for the present and future generations. Passive treatment systems are a method for successively removing acidity and metals from acid mine drainage in a human-made bio-system that capitalizes on biological and geochemical reactions [31]. Passive treatment systems are considered to be eco-friendly, low energy, environmentally sustainable wastewater treatment systems. Passive treatment technologies are attractive sources of mine wastewater treatment in coal mines effectively, utilized since, 1970[32]. The primary passive treatment systems (some important systems are shown in figure,3-9[33] are limestone, limestone pond [32,34], anoxic and oxic limestone drains, open limestone channel (OLC), reducing and alkalinity producing systems (RAPS), successive alkalinity producing system (SAPS),[35], limestone pond [32,36], microbial reactor, reactive walls and biosorption systems; are also reviewed [38] .Passive technology is used in the United Kingdom [39] since the early 1990s and also globly practices in many other parts of the world including, North America, and Western Europe [40].These attractive Passive technique having engineered based facilities utilized a series of treatment that requires negligible or no maintenance once constructed and operational(US EPA).Passive treatment systems, in many mines sites, are reducing the treatment cost. The effective selection of suitable passive treatment system depends on many important factors likes; local topography, site characteristics, water chemistry, flow rate [41], and research on economical design are in progress [37]. Passive treatments system offer suitable option for acid mine drainage treatment in small investment, likes, minimum Figure 3: Diagram of Typical Constructed Wetlands inputs, works without any usual information of cost-intensive resources, such as technical human resources, chemicals and energy, no external energy required, reduce operational and maintenance cost [42-43].Presently, Reduce, recycle, reuse and recovery are a very traditional process for the effective management of the natural environment.



Natural Wetlands

Natural Wetlands are complex ecosystems worldwide used for assimilating large amounts of environmental contaminants [44].These systems are categorized by water-saturated and soil with vegetation. This improves the water quality naturally through the process of physical, chemical, microbial and plant-mediated [27]. More than a thousand of natural wetlands are used for the treatment of mine water discharges from active and abandoned mine sites [45]. Mine water contains suspended (SS) solids, and heavy metals are easily filtered and retained in wetlands [46].

Aerobic wetlands

Aerobic wetlands are the simplest form of the passive treatment system and designed to encourage the precipitation of hydroxides or metal oxides by maintaining suitable residence time and aeration. Aerobic wetlands are cattails, vegetated with emergent plant species; which required 150 mm to 250 mm water level for the maintenance of the aerobic condition. The size and treatment efficiency of Aerobic wetland system mainly depends on the characteristic of effluents ingoing to the swamp. At a site in Ohio, United states, metal sludge is accumulating at a rate of about 30-40 mm per year [47-48].Many studies at some sites in Pennsylvania, USA, show the accumulating sludge rate ranges from 32 to 44 mm per year [48].These data suggest that a suitable freeboard of 914mm provide sufficient volume for 25-50 years of treatment. Wetland plants remove toxic metals from acidic water by adsorption [49]. The removal capacity of wetlands depends on many factors like, concentrations of dissolved metals, dissolved oxygen, air, pH, the alkalinity of AMD, chemistry of mine water, availability of energetic microbial biomass and detention time [50], for acidic water, it required large surface area and longer detention times [50]. Aerobic wetlands also create sufficient new removal sites, option for long-term treatment in low maintenance and economic cost [43].

Anaerobic wetlands

This is the modified form of natural wetlands including cattails and other vegetation over the water. Anaerobic wetland contains 300-600 mm layer of organic matter over 150-300 mm bed [49] of limestone or placing a layer of a mixture of organic matter and limestone to a depth of 50-1000 mm [49]. The AMD can be gradually passed through the layer of municipal waste composted materials, cow/horse manure with straw [51], hay and sawdust of softwood [52], spent mushroom compost, sludge generated from paper industries and wooden chips [53]. Micro-organisms present in the layers of organic materials decrease sulfates increase alkalinity and raise the pH value of the acid mine drainage. However, the treatment efficiency and mechanism of the system depend on the seasonal variation and with wetland age [54].

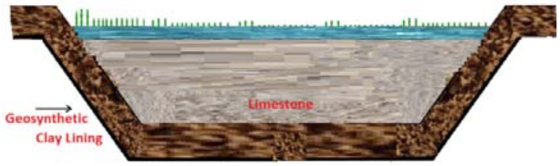


Figure 4: Diagram of Typical Aerobic Wetlands

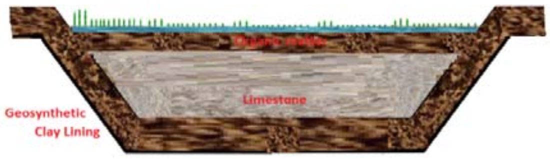


Figure 5: Diagram of Typical Anaerobic Wetlands

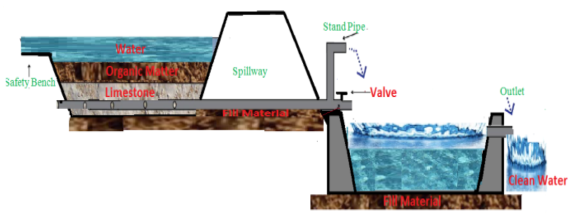


Figure 6: Diagram of Typical Successive Alkalinity Producing Systems (SAPS)

Figure 7: Diagram of a Typical Limestone Pond

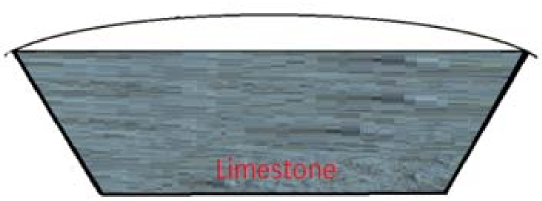


Figure 8: Diagram of a Typical Anoxic Limestone Drains (ALD)

Anoxic limestone drains

Anoxic limestone drains (ALDS) have been developed by Tennessee Valley Authority in the early nineties [55] and utilized in the many parts of the USA [56]. ALDs are limestone-filled trenches of typically having length 25-100 m, width 1.0-7.0 m and 1.0 m thick [48]. This system produces bicarbonate alkalinity via limestone dissolution, which helps in reduction of wetland sizes. The pH of the ALDS effluent ranges between 6.0 to7.5 [50].This system required 14-15hours retention time [57] to maintain the efficiency and construction cost of alkalinity generation with more removal capacity of heavy metals than the natural wetlands [58].

Open limestone channels (OLCs)

These Channels are very similar to rock lined ditches, suitable for treatment of mine drainage (Skousen, Rose et al. 1998), which contains low alkalinity and high acidity with dissolved heavy metals. Open lime stone channels have been a more efficient treatment option [59]. During treatment where AMD must be transported over a few distance. Use of lined channel with limestone gives an effective alternative for uptake of iron [60]. During AMD treatment such channels become armored and clogging with metal. To reduce the risk of system failure and increase the life of the system, its required flow velocities more than 0.1 m/s for keeping hydroxide flocks in suspension and to clean precipitates from limestone surfaces [61].This types of situation can be achieved by providing channel slope 20% [63].This system individually not suitable for proper treatment of acid mine drainage (AMD)[62]. OLCs can be more efficient and effective option when technically and economically construction of ALDS, compost wetland and RAPS is not feasible [48] for mine drainage treatment.

Vertical flow systems

The vertical flow systems are a combination of anoxic limestone drains (ALDs) and anaerobic wetlands, constructed within a water-tight basin; this system compensates the limitation of both systems [64]. In the vertical flow systems, a layer of an organic and limestone is the main constituent elements. This method is also called as Successive Alkalinity Producing Systems (SAPS) [65] and reducing and alkalinity producing systems (RAPS), [35], consist of layers that include standing water, organic matter and gravel of limestone [65]. In SAPS, acid water is filled from 10.0 to 30.0 cm over 20 to 30 cm of organic compost, and it first flows down through organic layer, which is underlain by 50 to 100 cm of limestone. Vertical flow systems are similar to the anaerobic wetland; the only difference is AMD is forced over the limestone layer. Which provide suitable contact time with limestone and the organic matter. The vertical flow systems are constructed in a water-tight basin with a standpipe to maintain the submerged state for the layers of natural and limestone in the system; a flushing pipe is provided in the drainage system to evade blockage over the limestone layer due to the precipitates of metals and iron [66]. This system can also be used in series to produce alkalinity consecutively for proper acid mine treatment.

Limestone Ponds

This type of the pond is a new form of passive treatment system [32]. Which is suitable for low dissolved oxygen (DO) to contain water, no containing Fe^{3+}, and Al^{3+}, and constructed on the flow of an AMD, Underground water discharge or seep point. A layer of crushed limestone is spread over the base of the pond, and the upward flows of water maintain through the packed limestone [86]. The efficiency of limestone ponds depends on many factors like the topography of the area, the size of Ponds, and the configuration of discharge zone. The depth of water can vary from 100 cm to 300 cm; maintain limestone, 30 cm to 100 cm for the retention time 1.0 or 2.0 days in ponds. Limestone Ponds required periodically maintenance for continuing the treatment efficiency. After prolonged treatment of the AMD, limestone materials become weary by suspension and acid neutralization, LP required fresh limestone materials over the seep. However, this system required regular maintenance for maintaining the treatment efficiency.

Diversion well (DW)

The construction of diversion well (DW) is a very easy, made of metal, concrete or other materials in the shape of cylinder or vertical tank of diameter 1.5-1.8m and depth 2-2.5 m, filled with (crushed) sand-sized limestone aggregate, erected in or near a stream (Figure.9) and connected by 0.20-0.30 m dia. Pipes placed vertically downward in the center of the well which shortly ends above the bottom face of the well. Theses device was developed in Norway and Sweden for the removal of acidity caused by acid rain [50, 70] from the stream. In some eastern part of the USA, also used for the treatment of (AMD) since the early 1990's [70].The wall needs to be placed so that, acidic water pass through the diversion well, the pH value increased in very less retention time, but for achieving required degree of treatment to maintain water quality standard, diversion wells required frequently cleaning of limestone placed in diversion wells.

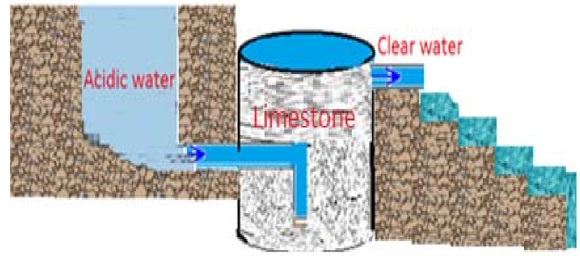


Figure 9: Diagram of a Typical Diversion well

Reverse Osmosis (RO)

In the RO system, semi-permeable membranes are used to treat AMD. In this system, Pressure is applied on the AMD and passed through the membrane, which only permits solvent; obstruct solute in the concentrated form on the AMD side of the semi-permeable membrane. This is a more useful option for the removal of heavy metal at a wide range of pH, 3-11, for a chemical solution, metals removal efficiency reported up to 97% with a metal concentration range varies from 21 to 200 mg/L. This system also suitable for removal of metals from different industries likes, electroplating, paper and pulp ,coal and metal mining, petrochemical, textile, metal finishing, food processing industries, including municipal wastewater, contaminated groundwater and radioactive effluent [71-72], with recovery of aluminum, copper, copper cyanide, chromium, gold, nickel, zinc,[71].This system has many drawbacks, including high treatment, operational and membrane cost. RO system also required high pressures for adequate separation which increases the requirement of energy.

Ion exchange

This system is recognized as a treatment process in the coal and minerals industries and provides an important option to the other procedures such as adsorption, distillation, and filtration. It is also used for the removal of metals from industrial effluent, separation of gas mixtures, and catalysis of organic from cooling water. It also plays This system plays a major role in the cleaning and demineralization of water and able to absorb H^+ ions, from acid mine drainage, increase the pH level [73] and remove copper and zinc [74].

Electrochemical Concentration

In this techniques combinations of magnetic, electrical, chemical, and plasma is used to remove metals ions from the acid mine drainage. This system also includes electro winning, solvent extraction, Pulsed Plasma and Magneto-Electrochemical technology; Ion Conduction Agglomeration and Alternating Current Electro coagulation. These types of techniques are focused on the metal ion removal and its cost recovery, but none are in regular use for treatment of AMD [27]. One of the major problems related to the regular requirement of electrical supply [74].

IV Conclusion

Waste water generated from Coal and minerals mines had severe effects on many sites all over the world and required proper treatment and effective management. Its generation depends on many environmental circumstances. The choice of suitable treatment option depends on several environmental factors. Sometimes the actual environmental cost of a remediation system is not instantaneously apparent. One such cost is the amount of fossil fuel energy needed to transport liming materials, often very long distances from source to mine sites. Usually, mine water acidic in nature and having large volume have been treated by active treatment system. In the case passive treatment system, required area could be made considerably smaller by focusing on optimizing biological treatment system. They can play the important role as either stand-alone treatment strategies or as pre-treatment to reduce the treatment cost and increase the efficiency of the active treatment system. Passive treatment systems are capable at renovating water quality of low pH, high acidity, and heavy metals of elevated levels.

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