

**SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING
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**EFFECTIVE ACID MINE DRAINAGE TREATMENT USING
NATURAL ZEOLITE AND HYDRATED LIME (PENGKALAN HULU)**

By

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of the requirements for the degree of Bachelor of Engineering with Honours
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DECLARATION

I hereby declare that I have conducted and completed the research work and work the dissertation entitle “**Effective Acid Mine Drainage Treatment Using Natural Zeolite and Hydrated Lime (Pengkalan Hulu)**”. I also declare that it has not been previously submitted for award of any degree or diploma or other similar title of this for any other examining body or university.

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“In the name of Allah, the Most Gracious, the Most Compassionate”

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LIST OF ABBREVIATION

Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
DO	Dissolved Oxygen
DOE	Department of Environment Malaysia
Hg	Mercury
JMG	Mineral and Geoscience Malaysia
MRC	Mineral Research Centre
Ni	Nickel
ORP	Oxidation Reduction Potential
Pb	Lead
ppm	Part per million
TDS	Total Dissolved Solids
TSS	Total suspended solid
RDO	Rugged Dissolved Oxygen
Zn	Zinc

**KEBERKESANAN RAWATAN SALIRAN LOMBONG BERASID
MENGUNAKAN ZEOLITE ASLI DAN KAPUR TERHIDRAT
(PENGKALAN HULU)**

ABSTRAK

Saliran lombong berasid adalah tumpuan baru yang menjadi fokus utama oleh industri kuari dan perlombongan di seluruh dunia disebabkan oleh kesan kesihatan dan alam sekitar yang berpunca daripadanya dan berpotensi membawa bahaya kepada masyarakat sekeliling. Tumpuan utama terhadap masalah ini adalah ion logam berat yang jatuh ke dalam julat submicron dan larut dalam air telah terbukti menyebabkan kesan kesihatan yang lebih parah berbanding kesan yang diberikan oleh zarah kasar ion logam berat. Air sungai merupakan sumber utama air untuk pelbagai kegunaan di mana pencemaran berpunca dari aktiviti pertanian dan perlombongan di kawasan ini telah menjejaskan saliran air sungai yang jelas memberi bahaya kepada kawasan persekitaran. Kini banyak penyelidikan telah dilakukan untuk saliran lombong berasid tetapi penyelidikan yang telah dilakukan adalah kurang tertumpu pada saliran lombong berasid sebenar. Tesis ini membentangkan hasil kajian yang dijalankan di Kelian Intan, Pengkalan Hulu, Perak di mana sampel air saliran lombong berasid sebenar diambil untuk dirawat. Projek ini dijalankan untuk menyiasat keberkesanan media (kapur terhidrat atau zeolit asli) untuk merawat saliran lombong berasid dari kawasan ini di mana kebiasaannya kajian yang dilakukan sebelum ini adalah tertumpu menggunakan simulasi sampel saliran lombong berasid. Walaupun pemantauan rapi di saliran lombong asid itu sudah dilaksanakan, tetapi masalah ini masih mempengaruhi kawasan itu. Projek ini adalah penting kerana untuk mematuhi standard yang ditetapkan oleh Jabatan Alam Sekitar dan Jabatan Mineral Geosains yang bertujuan untuk melindungi kualiti alam sekitar.

EFFECTIVE ACID MINE DRAINAGE TREATMENT USING NATURAL ZEOLITE AND HYDRATED LIME (PENGKALAN HULU)

ABSTRACT

Acid mine drainage is the new focus faced by industries of quarries and mining worldwide due to the health effects and environmental effect it can potentially bring to the surrounding communities. Of particular concern are the heavy metal ion that fall into the submicron range and soluble in the water, which have been shown to cause more grievous health effect than coarse particle. The river water is the main source of water for various uses and purposes where the contamination due agricultural activities and mining activities in this area does affect the stream which is obviously danger to the surrounding. For today, many research has been done for acid mine drainage however less is done on real acid mine drainage. This thesis present the results of a study conducted in Kelian Intan, Pengkalan Hulu, Perak where real acid mine drainage water sample is taken to be treated. This paper is purposed to investigate the effectiveness of which media (hydrated lime or natural zeolites) to treat acid mine drainage from this area rather than usually study that used simulated acid mine drainage water. Even though close monitoring on the acid mine drainage has been done, but this problem is still affecting the area. The project is important as to comply standard set by the Department of Environment and Mineral Department of Geoscience which is intended to protect environmental quality. Hence, if this project able to manipulate the parameter for water quality, we can improve its quality to find better solution to this problem.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND RESEARCH

Acid mine drainage is the most serious environmental problem faced by the metal mining industries. Some effluent generated by the metals mining industry contains major quantities of toxic substances such as cyanide and heavy metals which have serious human health and ecological impact.

An acid mine drainage can give severe damage and destroy our rivers, streams, aquatic life and even plants for hundreds. Acid drainage is enriched with iron, aluminium, sulfate and heavy metals and also extremely acidic (pH as low as 2).

Acid mine drainage is formed when sulphide minerals are oxidised in the presence of water and oxygen to form highly acidic, sulphate and metal rich drainage. Release of various toxic metals in soil and groundwater causes high magnitude perturbation of the ecosystem (Doye and Duchesne, 2005)

The initiation of acid mine drainage begins by the chemical oxidation of sulphide mineral by oxygen and water to produce sulfuric acid that lowers pH. The acid run-off further dissolves heavy metals such as copper, lead, mercury into ground or surface water. As the reaction proceeds, temperature and acidity increase resulting in an increased rate of reaction. Between pH levels of 2 to 4, bacteria and ferric iron catalyse the reaction and rates can be 20 to 100 times faster than the original chemical reaction rate (Mclemore, 2008)

The water that is impacted by acid mine drainage must be treated in order to stop any more problems from starting in the stream or river and to help reverse any effects that had occurred in the area where the drainage is entering the water. There are systems today that are installed in the affected areas to manage the drainage that comes into the water flow. These systems are classified two system where they either treat with chemicals which is known as active treatment or by using natural and biological processes which also known as passive treatment.

There are many studies that has been done in recognition of acid mine drainage but this problem is still occur and will affect the next generation. This problem is getting attention and many regulation has been done in order to keep the ecosystem balance. The regulation that is used for this research is Environmental Quality (Industrial Effluent) Regulations 2009 which use Standard B as guidance and directory.

1.2 PROBLEM STATEMENT

Acid mine drainage produced in the tin mining area has the potential to cause environmental degradation to ecosystems, human health and threatens the water security of the area. Besides this mines has been operating for 100 years and still operating till today. 100 years before, environment is not considered in the mining activities and when the steps want to be taken from today, the obstacle that need to be faced is very huge.

This project is focused on the removal of heavy metals and the pH value of the acid mine drainage water by using active treatment of ion exchange which is zeolite and metal precipitation which is hydrated lime. Although there is many studies that exist that study on absorption and neutralisation of acid mine drainage, most of the studies is done on simulated acid mine drainage and little attention is given to real acid mine drainage. Therefore this study evaluated metal precipitation and ion exchange from real acid mine drainage solution.

1.3 OBJECTIVES

The objectives of this research are:

1. To analyse characteristic of AMD water sample and composition of adsorbent media.
2. To compare the effectiveness of zeolite and hydrated lime.

1.4 SCOPE OF STUDY

The observation was made at Kelian Intan, Pengkalan Hulu, Perak where it is situated near to a tin mine and agricultural activities. The observation are carried out on 7/2/2017-8/2/2017 at the stream chosen based on topography map and site recommendation. Two media, hydrated lime and natural zeolite is used as treatment media to investigate their ability to treat acid mine drainage by removing the heavy metal and increase the pH value. Hydrated lime and natural zeolite is provided by Mineral Research Centre. Parameter studied were pH and heavy metal concentration of element Al, Cd, Cu, Fe, Mn, Ni, Pb and Zn. The experiment is divided into two phase. The first one was in-situ field measurement and the second one was column test experiment.

1.5 THESIS OUTLINE

This research is presented in five chapters including this introductory chapter.

- **Chapter 1. Introduction:** introduces the background of this study, presents the problem statement, list the objectives and scope of this research.
- **Chapter 2. Literature Review:** contains the following sections: acid mine drainage formation, effect of acid mine drainage, acid mine drainage treatment and treatment media for acid mine drainage,
- **Chapter 3. Material and Methods:** presents the (1) site selection, (2) data collection, (3) data analysis and finally (4) results and discussion. Experimental program and the procedures of in-situ field measurement and column studies in addition to the site condition, location, samples preparation and the main methods used to determine water sample properties and the characteristics of media used in the study.

- **Chapter 4. Results and Discussion:** includes analysis of the results obtained from the experimental work. The characterization of water sample and media use to treat acid mine drainage. Analysis of ICP results obtained from the experiments and analysis of the effect of pH on the removal efficiency.
- **Chapter 5. Conclusion and Recommendations:** summarizes the finding of the research and makes recommendations based on it.

CHAPTER 2

LITERATURE REVIEW

2.1 ACID MINE DRAINAGE FORMATION

Acid mine drainage is one of the most serious mining threat to the water because it can devastate rivers, streams, and aquatic life for hundreds, and thousands of future years. Our new generation will be the most affected if this threat is not prevented and ignored. A literature review on acid mine drainage concluded that “no hard rock surface mines exist today that can demonstrate that acid mine drainage can be stopped once it occurs on a large scale.” (Earthworksaction,2016)

Acid mine drainage is formed when rocks containing sulphide-bearing minerals such as pyrite are exposed to oxygen and water. Pyrite (FeS_2) and marcasite (FeS_2) are the predominant “acid” forming sulphide minerals present in mining situations, with other important metal sulphides including pyrrhotite (FeS), chalcopyrite (CuFeS_2), and arsenopyrite (FeAsS). (Jeff et. al, 2005). Although this process occurs naturally, quantity of sulphide exposed and naturally occurring bacteria can accelerate acid mine drainage production by assisting in the breakdown of sulfide minerals which result from mining activity. Acid mine drainage can severely contaminate surface, groundwater and soils which is characterized by low pH and high concentrations of heavy metals.

Upon exposure to oxidizing conditions, acidic sulfate-rich drainage is formed where the sulfide minerals are oxidized in the presence of water and oxygen. The oxidation of sulfide minerals and its subsequent acidity occurs through several reactions.

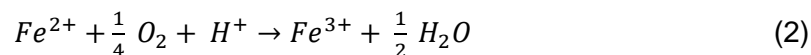
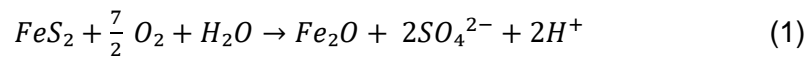
The acid generation primary ingredients are as follows:

- (1) Sulfide minerals;
- (2) Water or a humid atmosphere;
- (3) An oxidant, particularly oxygen from the atmosphere.

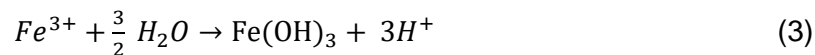
In the majority of cases, bacteria play a major role in accelerating the rate of acid generation (Akcil and Koldas, 2005). Releases of acid mine drainage have low pH, high specific conductivity and high concentrations heavy metals.

The reaction of pyrite upon exposure to air and water are as follows:

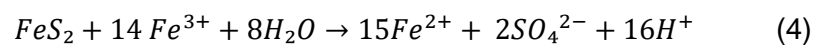
Pyrite is initially oxidized by atmospheric oxygen producing sulphuric acid and ferrous iron (Fe²⁺) according to the following reaction:



The ferrous iron may be further oxidized by oxygen releasing more acid into the environment and precipitating ferric hydroxide:



The pH of the solution decreases as acid production increases, resulting in further oxidation of pyrite by Fe³⁺, resulting in more acid production:



The primary factors that determine the rate of acid generation are:

- a) pH
- b) Temperature
- c) Oxygen content of the gas phase, if saturation is less than 100%
- d) Oxygen concentration in the water phase
- e) Degree of saturation with water
- f) Chemical activity of Fe^{3+}
- g) Surface area of exposed metal sulfide
- h) Chemical activation energy required to initiate acid generation
- i) Bacterial activity.

Chemical, biological and physical factors are important in determining the rate of acid generation. For bacteria to thrive, environmental conditions must be favourable. For example, at pH of less than 3.2 Ferrooxidans is most active in water. If conditions are not favourable, the bacterial influence on acid generation will be minimal. (Akcil and Koldas, 2005).

This formation of acid mine drainage is quite complicated since factors like microbial activities, temperature (weather and seasonal conditions), availability of oxygen and type of mineral deposits vary from place to place, thus influencing the quality (pH and metals content) and amount of AMD produced.

2.2 EFFECT OF ACID MINE DRAINAGE

Acid mine drainage contains high concentrations of acid and dissolved heavy metals. These heavy metals pose a serious threat when this toxic mixture flows into groundwater, streams and rivers to human health, animals and ecological systems it give rises to several environmental problems and toxic to aquatic organisms and also destroys ecosystems.

Effect of Heavy Metal

The danger of heavy metal pollutants in water lies in two aspects of their impact with regards to humans and animals. Firstly, at a longer period of time heavy metals have the ability to persist in natural ecosystems. Secondly, they have the ability to accumulate in successive levels of the biological chain, thereby result in chronic diseases. In general, the toxicity or poisoning of heavy metals results from the disruption of metabolic functions (Simate and Ndlovu, 2014).

Heavy metals disrupt the metabolic functions in two ways:

- (1) They disrupt the important functions accumulate in vital organs and glands such as the heart, brain, kidneys, bone and liver.
- (2) They hindering their biological functions by inhibiting the absorption, interfere with or displace the vital nutritional minerals from their original place.

These heavy metals can act together to oppress algal growth, affect fish and other organisms that live on, in or near the seabed. The dissolved metals can precipitate out of solution as hydroxides if the conditions allow. The formation of precipitates consumes dissolved oxygen, thereby oxygen content is reduced and less is available for aquatic organisms. When formed, these hydroxides may coat fish body surfaces and cover the bottom of the stream hence making it unfit for habitation by benthic organisms (Motsi, 2010).

Effect of low pH

The pH of acid mine drainage is critical to determine its environmental impact to the potential effects of mine drainage on plants, aquatic and animal life which is severe due to lower pH. Death can occur due to respiratory or osmoregulatory failure if the pH falls below the tolerance range. Acid mine drainage also affects manmade structures, mainly because of its corrosive nature (Motsi, 2010).

Plants need a proper balance of micronutrients and macronutrients in the soil where the soil pH has an important influence on the availability of nutrients and on the growth of different kinds of plants. There are many affect when the soil pH is low such as when the nitrogen, phosphorus and potassium are tied up in the soil and not available to plants. Calcium and magnesium may be absent or deficient due to low pH soils and toxicity of the soil may be increased due to elements such as aluminium, iron (Simate and Ndlovu, 2014).

2.3 ACID MINE DRAINAGE TREATMENT

2.3.1 ACTIVE TREATMENT

Active treatment, also known as chemical treatment, where there are several different chemicals that are in use to combat acid mine drainage that involves adding chemicals to the water to raise pH and precipitate metals. This methods also involves the use of machinery to put the chemicals into the water where it can be very effective, as effective as any passive method, but treatment is determined on a site by site basis.

Active treatment are methods that need continuous inputs of resources to sustain the process where it often included technologies such as aeration, neutralization, membrane processes, ion exchange, and biological sulphate removal (Ochieng et al., 2010). Active treatment is described by a continuous treatment plant of on-going flow of chemicals into and out (Johnson and Hallberg, 2005). It may include the installation of a water treatment plant with a variety of reactor systems, where in the plant, the acid is first neutralized by dosing the acid mine drainage with lime or limestone and then it is passed through settling tanks to remove sediments and particulate material.

Active treatment systems can also be a very expensive option due to the cost of lime (Johnson and Hallberg, 2005). Weather, equipment failure, and budget restrictions can result in lapses in treatment, which in turn can result in massive death of aquatic life (Ochieng et al., 2010). Other active treatment technologies such as membranes and ion exchange can also produce water of acceptable standards. Below is a brief outline of some of the active treatment methods.

Ion exchange

A potential treatment for acid mine drainage has been previously investigated where it is known as cation exchange processes (INAP, 2003). The principle is that an ion exchange resin can remove potentially toxic, or chlorides, sulphates and uranyl sulphate complexes from mine water. Once the contaminants are adsorbed, the exchange sites on resins must be regenerated, which typically requires acidic and basic reagents and generates a brine solution that contains the pollutants in a concentrated form.

Adsorption

Adsorption is an alternative for active treatment that has emerged to treat solution that contain low metal ion concentrations which are still above the permissible discharge levels because there are some active treatment methods discussed earlier are ineffective due to low metal removal efficiency and high treatment cost for low contaminant concentrations. This is a result of the high selectivity, low operational cost and minimal toxic sludge associated with the adsorption process (Kurniawan et al., 2011).

An adsorbent can be considered as cheap or low cost if it is abundant in nature, and it requires little processing and is a by-product of waste material from industry. Due to the challenges encountered in active treatment technologies; an alternative will be to apply passive treatment technologies which use natural ameliorative processes. The low-cost adsorbent that is widely used is (1) chitosan, (2) zeolites, (3) fly ash, (4) coal, (5) activated carbon and many more (Babel and Kurniawan, 2002).

2.3.2 PASSIVE TREATMENT

Passive treatment involves the diversion of water into a pond or wetland where it often use natural processes to treat acid mine drainage. Unlike active treatment chemicals are not added to the water and it uses only naturally available energy sources such as gravity, microbial metabolic energy, photosynthesis etc. where the affected water is diverted through natural or biological treatments to achieve similar results as the chemical treatments (Johnson and Hallberg, 2005).

The passive treatment methods needs little maintenance to remediate acid mine drainage that employ naturally occurring chemical and biological reactions where it use treatment systems such as constructed wetlands, diversion wells containing crushed limestone, or open ditches filled with limestone and bioreactors (EPA, 2008). Passive treatment on its own is, therefore, unlikely to offer a sustainable solution to the large volumes of AMD (Johnson and Hallberg, 2005). The widely used passive treatment methods include constructed wetlands, anoxic lime drains, alkalinity producing systems, in-situ treatment is an illustration of some of the passive methods, showing various dimensions normally used for each method.

2.3.3 TREATMENT MEDIA FOR ACID MINE DRAINAGE

2.3.3.1 ZEOLITE

Zeolites occur in nature and have been known for almost 250 years as aluminosilicate minerals. Examples are clinoptilolite, mordenite, offretite, ferrierite, erionite and chabazite. Nowadays, most of these are in great interest in heterogeneous catalysis yet their naturally occurring forms are of limited value.

Zeolites consist of a wide variety of species such as clinoptilolite and chabazite. Clinoptilolite is most abundant in nature and is readily available from more than 40 natural zeolites species. Among the most frequently studied natural zeolites, clinoptilolite was shown to have high selectivity for certain heavy metal ions such as Pb^{2+} , Cd^{2+} , Zn^{2+} , and Cu^{2+} (Vaca et.al, 2001).

Clinoptilolite is the natural zeolite used in this research as the low cost material for the removal of heavy metals from acid mine drainage. The selectivity of the series of the heavy metals studied was determined to be as follows:

- Pb^{2+}
- Cd^{2+}
- Cu^{2+}
- Co^{2+}
- Cr^{3+}
- Zn^{2+}
- Ni^{2+}
- Hg^{2+}

(Zamzow et. al, 2006)

2.3.3.1.1 OCCURRENCE OF NATURAL ZEOLITES

Zeolites occur in rocks of many types, ages and geological settings. The principal geologic settings of zeolites are (1) saline, alkaline lakes, (2) saline, alkaline soils, (3) deep-sea sediments, (4) low-temperature open hydrologic systems, (5) burial diagenesis, and (6) hydrothermal-geothermal systems (Hay, 2009). Zeolites are formed by reaction of pore water with solid material where some common solid material reactants in zeolite formation are montmorillonite, volcanic glass (debris), nepheline, plagioclase, poorly crystalline clay and quartz. Zeolites and clay can be formed from the same material, but whether it is zeolite or clay that is formed depends on the physical environment and the activities of dissolved species such as H⁺ ions, alkali- and alkaline earth ions (Sand and Mumpton, 1978). The more common zeolites are clinoptilolite, analcime, heulandite and phillipsite.

2.3.3.1.2 FRAMEWORK AND STRUCTURE OF ZEOLITES

Basically zeolites are a naturally occurring crystalline aluminosilicates consisting of a three dimensional and regular framework formed by linked TO₄ tetrahedral molecules (T = Si, Al...), linked with each other by shared oxygen atoms (Weitkamp and Puppe, 1999). Each oxygen atom is shared between two tetrahedral Al and Si atoms; this creates infinite lattices comprised of identical building blocks (cell units) in a way typical for crystalline materials (Dyer, 1988).

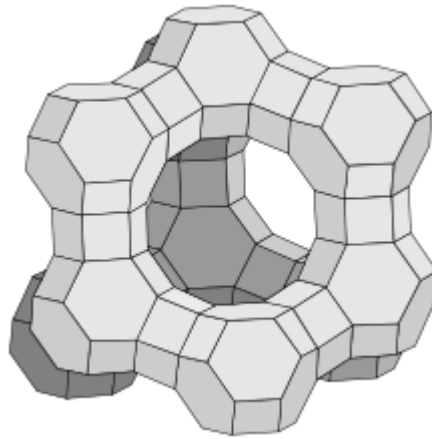


Figure 2.1: schematic representation of the framework of a zeolite

It has channels and cavities with molecular sizes which can host the charge compensating cations, water or other molecules and salts. The microporosity must be “opened” and the framework must have enough stability to allow the transfer of matter between the interior of the crystal and the exterior.

Figure 2.1 shows that the crystalline structure of the zeolite adsorbent with a general unit cell composition of $[\text{Na}_{12}(\text{Al}_{12}\text{Si}_{12}\text{O}_{48})\cdot 27\text{H}_2\text{O}]$, and its Si/Al ratio is always close to 1.0 (Mumpton, 1999). The structure of zeolites consists of three-dimensional frameworks of SiO_4 and AlO_4 tetrahedra. The aluminium ion is small enough to occupy the position in the center of the tetrahedron of four oxygen atoms and the isomorphous replacement of Si^{4+} by Al^{3+} produces a negative charge in the lattice (Erdem et al., 2004). The net negative charge is balanced by an exchangeable cation (sodium, potassium, or calcium). These cations can be exchanged with noxious cations such as manganese, lead, cobalt, copper and zinc found in waste water solutions (Peric et al., 2004).

Without changing its crystal structure, zeolites are able to lose and gain water reversibly and also to exchange extra framework cations (Mumpton, 1999). In addition, by exposing the zeolite surface to high temperatures it can be modified by introducing functional groups on its surface to improve its selectivity for the substance to be removed. (Curkovic et al., 1997).

2.3.3.1.3 ZEOLITE WORKING MECHANISM

Zeolite contains cations and water molecules, when water is removed from zeolite, empty voids are created within its framework which can be occupied by other molecules. The occupation of these voids by other molecules (*guests*) is called adsorption.

Adsorption involves the movement or diffusion of solute molecules (adsorbate) from a bulk fluid to the surface of a solid (zeolite), forming a distinct adsorbed phase. The separation efficiency of an adsorption process depends on the selectivity and affinity of the adsorbent for a particular solute over another in the mixture (Richardson et al., 2002).

As highlighted previously, the structural architecture of zeolite is made up of channels of certain sizes and interconnected cages, which allow certain sizes of molecules to pass through whilst excluding others. They are used as molecular sieve due to property of zeolites, where it separate mixtures of molecules (liquid or gases) on the basis of their effective size and shape. The zeolite structure contains some cations that are readily to exchange for other types of cations from solution.

2.3.3.1.4 USING NATURAL ZEOLITE TO TREAT ACID MINE DRAINAGE

The treatment of acid mine drainage by natural zeolite is mainly where the exchangeable cations in the zeolite structure (Na^+ , Ca^{2+} , K^+ and Mg^{2+}) are displaced by heavy metal cations such as lead, copper, zinc, iron, nickel and aluminium which is known as ion exchange reaction (Barrer, 1978). The fact that using zeolite to displaced cations relatively harmless makes zeolite attractive for the removal of toxic and undesirable heavy metal ions from acid mine drainage effluents.

The other factors that make natural zeolite an attractive alternative for the treatment of acid mine drainage are:

- Cheap since they are relatively abundant
- Have a favourable cation exchange capacity
- They have good selectivity for cations
- Zeolites have a high surface area due to their porous and rigid structure
- They also act as molecular sieves and this property can easily be modified to increase the performance of the zeolite

Zeolites can be easily regenerated with little effect on their structure and adsorption capacity and it have good structural stability even in acidic conditions. Zeolites can neutralise acidic solutions where this is achieved through the exchange of H^+ ions from solution with the exchangeable cations in the zeolite structure (Leinonen and Lehto, 2001).

2.3.3.2 HYDRATED LIME

Limestone is an abundant sedimentary rock and naturally occurring rock that consisting of high levels of calcium and/or magnesium carbonate and/or dolomite (calcium and magnesium carbonate), along with minerals. Lime production begins by extracting limestone from quarries and mines. Calcium hydroxide (traditionally called slaked lime) is an inorganic compound with the chemical formula $\text{Ca}(\text{OH})_2$. It is a colorless crystal or white powder and is obtained when calcium oxide (called *lime* or *quicklime*) is mixed, or slaked with water.

2.3.3.2.1 HYDRATED LIME PREPARATION

Hydrated lime is prepared from when limestone enters a primary crusher to break the rock. Varying size of the feedstone makes limestone may go through a secondary or tertiary crusher to further reduce its size. The stone is then screened into various sizes ranging from several inches to dust-sized particles and it is then washed.

The next stage is preheating where limestone is heated by direct contact with kiln exhaust gases that enter the preheater kiln. In this processed, stone is transported by conveyor belt to the lime kilns. A significant transfer of heat to the limestone is needed to cook or “calcine” limestone. In general, the heat transfer from the fuel source to limestone can be divided into two stages:

- Calcining – the kiln fuel is burned in the preheated air from the cooling zone and, as the limestone moves down the kiln, the heat turns the limestone into quicklime and carbon dioxide (CO_2).
- Cooling – quicklime leaving the calcining zone is cooled by direct contact with “cooling air.”

Limestone is fed into the upper or "back end" of the kiln, while fuel and combustion air are fired into the lower or "front end" of the kiln. As it moves down the kiln toward the lower end the limestone is heated and as it moves through the kiln, it is "calcined" into lime. The lime is discharged from the kiln into a cooler where it is used to preheat the combustion air. Lime can either be sold as is or crushed to make hydrated lime.

Quicklime is processed into hydrated lime by crushing the quicklime, adding water to the crushed lime (water accounts for approximately 1% of raw hydrate), and then classifying the hydrated lime to ensure it meets customer specifications before it is transported.

2.3.3.2.2 HYDRATED LIME NEUTRALISATION

The principle of lime neutralisation of acid mine drainage lies in the insolubility of heavy metals in alkaline conditions where by controlling pH to a typical set point of 9.5, metals such as iron (Fe), zinc (Zn), and copper (Cu) are precipitated (see Figure 2.2). Other metals such as nickel (Ni) and cadmium (Cd) require a higher pH, in the range of 10.5 to 11 to effectively precipitate the hydroxides. This creates larger and denser particles that can settle and compress better than the typical precipitates (Bernard).

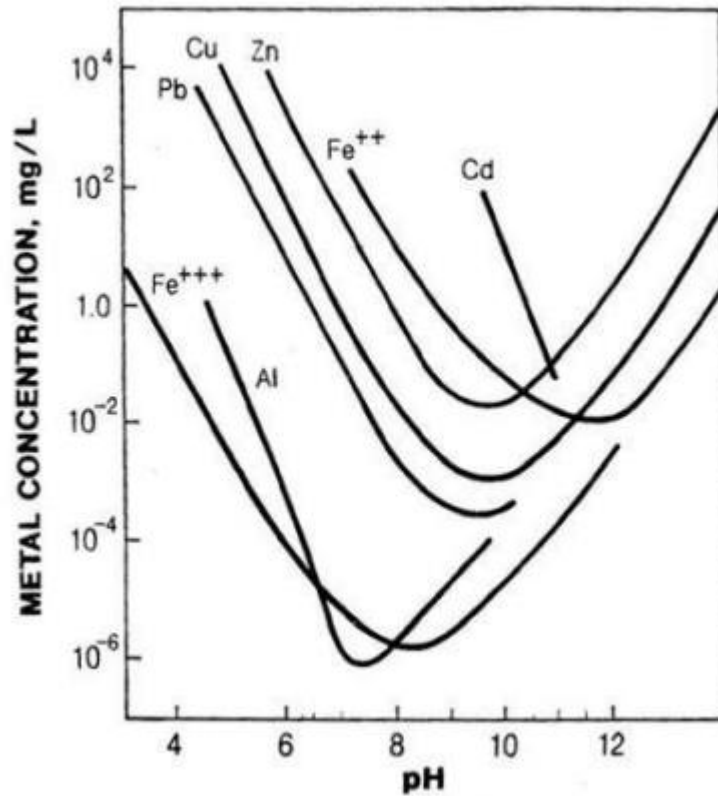
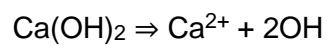
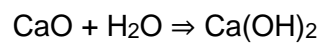
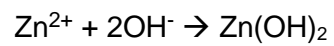
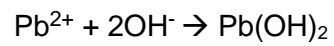
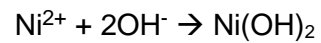
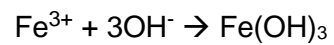
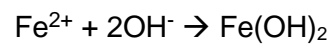
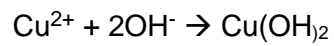
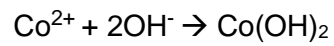
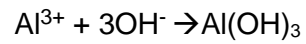


Figure 2.2: Metal Hydrolysis After (Aubé and Zinck, 2003)

Lime dissolution is the first step of the neutralisation process. For large treatment systems, hydrated lime is used and is normally fed to the process as a slurry. The hydrated lime then dissolves to increase pH. The two following equations illustrate these reactions:



The increased pH then provides hydroxide ions which combine with the dissolved metals to produce precipitates. The following equations show the precipitation reactions with different metals:



(Aube, 2004)

CHAPTER 3

RESEARCH METHODOLOGY

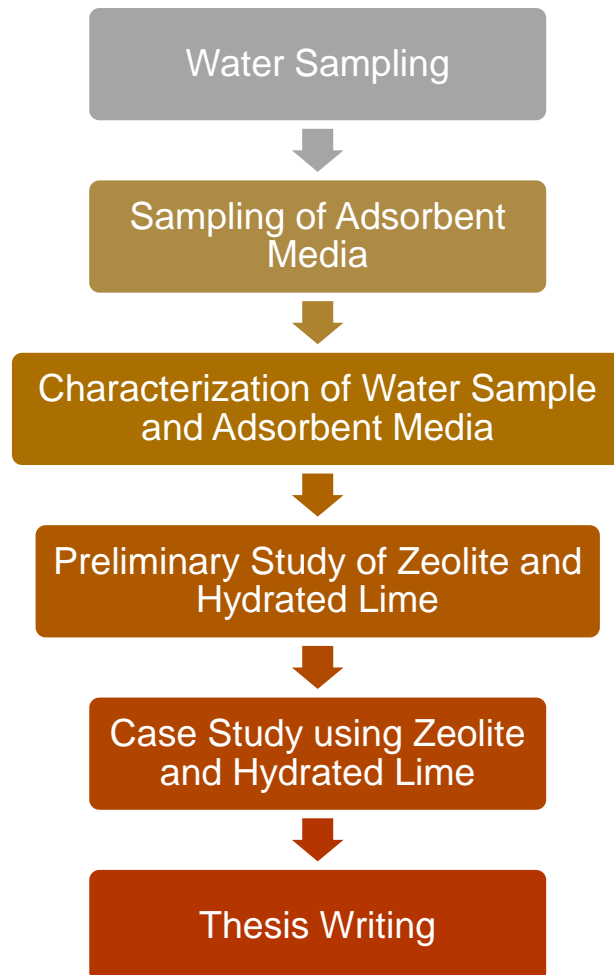


Figure 3.1: Research Methodology Flowchart

3.0 RESEARCH METHODOLOGY

The research is done in six (6) phase as shown in Figure 3.1 where it start with water sampling which first step start with water sampling which comprises of site selection and data collection. Second step is sampling of adsorbent media which involved hydrated lime and natural zeolite. Third step is characterization of water sample and adsorbent media where it involved the method of analysis using XRF and ICP. Fourth step is preliminary study of zeolite and hydrated lime using column test investigation and fifth step is the case study using the adsorbent media and the column test. Lastly, the sixth step is writing the report of the project.

3.1 WATER SAMPLING

3.1.1 SITE SELECTION

This study was conducted in a stream at Kelian Intan, it situated in 36km from Bandar Gerik and 15km from Pengkalan Hulu in the state of Perak, Malaysia. The location of the site is shown in Figure 3.2 below. Under the advice of the Mineral Research Centre, a division under the Mineral and Geoscience Department Malaysia (JMG) this site was chosen due to ease of access and security with help from the Mineral and Geoscience Department Malaysia of Perak (JMG Perak).