

The Use of Quicklime in Acid Mine Drainage Treatment

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In this study, quick lime or calcium oxide (CaO) is used to treat acid mine drainage (AMD). Quick lime was obtained from quarry in Simpang Pulai, Ipoh, Perak. Quick lime is produced by calcination process of limestone at a temperature around of 900 °C to 950 °C. Acid mine drainage (AMD) was collected from a tin tailing pond that located in Perak. Jar test method was used to study the effectiveness of quick lime in AMD treatment. There are five parameters of weights and six interval times used in the experiments. The weights of quick lime used in this study were 1 g, 1.5 g, 2.0 g, 2.5 g and 3 g. The interval times used were 10 min, 20 min, 30 min, 40 min, 50 min and 60 min. For each experiment, 1 L water sample was poured into a 2 L beaker and quick lime was added into the water sample. Mechanical stirrer with speed 700 rpm was used in all the experiments. The quick lime before and after treatment were analysed by using carbon and sulphur analyser for sulphur percentage. From the results of the jar test, quick lime is found to be capable to increase the pH value and decrease the amount of heavy metals such as arsenic, cadmium, chromium in AMD.

1. Introduction

Leopold and Freese (2009) had reported theoretically based on previous experiments that quicklime can be used in wastewater treatment and Tolonen et al. (2014) had reported that the by-product from quicklime manufacturing has potential to be used in treating acid mine drainage (AMD). Quicklime, with chemical formula, CaO, also known as calcium oxide or lime, was chosen in this study to treat AMD because of the presence of Ca element and hydroxide ion (OH⁻) after being dissolved in water, which can increase the pH value and reduce the heavy metals content. The physical properties of quicklime are: the molecular weight is 56.08 g/mol, the common colour is white but certain quicklime contains impurities that can cause grey, brown, or yellow tints colour due to the presence of iron and manganese, the odour is slightly earthy, the texture is micro-crystalline, the crystal structure is cubic, the specific gravity of zero porosity quicklime has a range of between 3.25 to 3.38 g/cm³, and the melting point is 2,580 °C (Oates, 1998). The chemical properties of quicklime are: the heat energy produced when quicklime reacts with water is 1,140 kJ kg⁻¹, has the tendency to absorb water, reacts with water to produce hydrated lime or calcium hydroxide, cannot react with metals without water and reacts with carbon at temperatures 1,800 to 2,100 °C to produce calcium carbide (Oates, 1998).

AMD can be classified as high acidity, contains sulphate and heavy metals such as copper, iron, manganese, lead and can give dangerous effect to the terrestrial and aquatic life (Bai et al., 2012). AMD occurs when sulphide minerals are exposed to air and water under the presence of bacteria that can accelerate the cause of AMD (Akcil and Soldas, 2006). Common sulphide minerals that can cause AMD are pyrite, chalcopyrite, chalcocite, and arsenopyrite. There are many methods to treat AMD such as chemical treatment, ion exchange and membrane (Madzivire et al., 2010). In this study, active treatment by using chemical material (quicklime) and jar test were used to treat AMD. Many chemicals can be used as AMD treatment besides quicklime. For example, limestone (Hammarstrom et al., 2003), hydrated lime (Taylor et al., 2005), and calcium carbide (Othman et al., 2016). Besides chemicals, organic materials such as goat manure fertiliser (Othman et al., 2015) and spent coffee grounds (SCG) (Lavecchia et al., 2016) can also be used to treat polluted water such as AMD or industrial water. SCG suitable to be used as reducing lead content in polluted

water (Lavecchia et al., 2016) because it contains a lot of organic compounds such as fatty acids, amino acids, polysaccharides (Campos-Vega et al., 2015).

2. Experimental

2.1 Materials

Quicklime was obtained locally from a factory located near to a limestone quarry in Simpang Pulai, Ipoh, Malaysia. Water sample was collected from a tin tailing pond situated in Perak, Malaysia.

2.2 Methods

For each experiment, five different weight parameters of quicklime used were 1.0 g, 1.5 g, 2.0 g, 2.5 g and 3.0 g. Each weight of quicklime was added into a 2 L beaker that contained 1 L of AMD. The AMD that contained quicklime was stirred at 700 rpm by using mechanical stirrer. The AMD used in this study had pH value of around 2.6 and contained high concentration of sulphate and heavy metals such as arsenic, copper, lead, cadmium, and chromium. The method to carry out the experiments is known as the jar test. The jar test is one of the active treatment techniques. Figure 1 shows a jar test before and after reaction. After quicklime was added, the colour of AMD sample changed to orange and precipitation can be observed. The pH and heavy metals concentration of AMD were recorded before and after the treatment by using pH meter (A329, Thermo Scientific, Indonesia) and ICP-OES (Optima 5300 DV, Perkin Elmer, USA). AMD after treatment was filtered by using Whatman filter paper No.1. The residue was assumed as quicklime after treatment. Quicklime before and after reaction were analysed for sulphur and elemental oxides percentages by using Carbon and Sulphur Analyzer (G4 Icarus HF, Bruker, Germany) and Hand-held XRF (S1 Turbo, Bruker, USA).

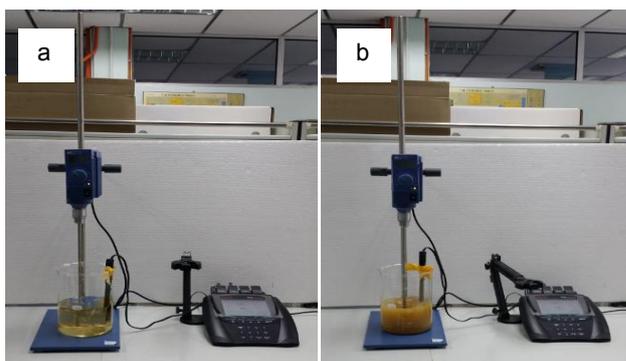


Figure 1: Jar test (a) before and (b) after reaction between AMD and quicklime

3. Results and Discussions

3.1 Quicklime

Figure 2 shows the percentage of sulphur in quicklime before and after reaction. The result indicates that sulphur precipitated in quicklime after the reaction and based on the percentage of sulphur, it shows that the sulphur had increased. The result also indicates that the percentage of sulphur precipitated was subjected to the weight of quicklime used. After the reaction, the percentage of sulphur dropped beginning with 1.0 g of quicklime until 3.0 g of quicklime. The decreasing of sulphur percentage after the reaction demonstrates that the relation between the weight of quicklime and sulphur percentage is not proportional. Sulphur was trapped in quicklime in the form of gypsum, CaSO_4 . Gypsum is commonly formed in active treatment and less formed in passive treatment (Riefler et al., 2008). The formation of gypsum can eliminate the content of sulphur in AMD (McCauley et al., 2009). The maximum percentage of sulphur trapped was 4.72 ± 0.02 % in 1.0 g quicklime. The reaction of gypsum formed is shown in Eq(1) (Abdelmsee et al., 2009).



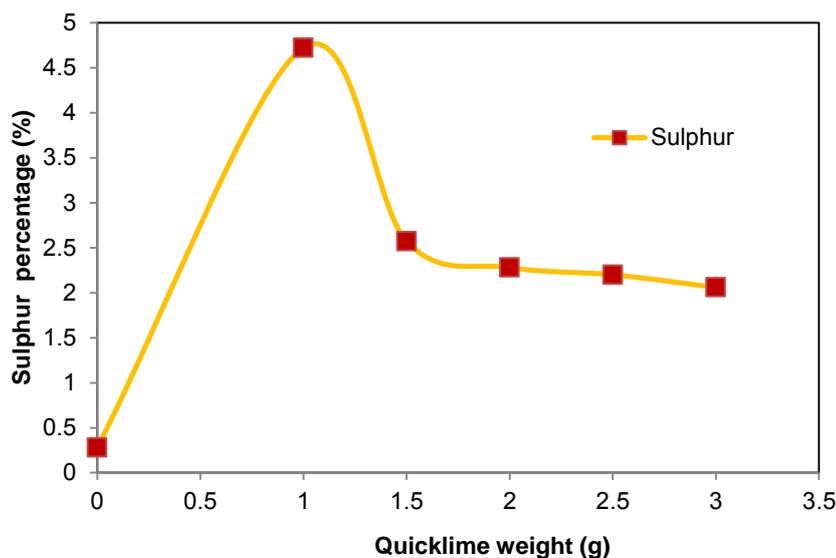


Figure 2: The percentage of sulphur in quicklime before and after reaction

Figure 3 shows the percentage of elemental oxides in quicklime before and after the reaction. Figure 3 shows that percentage of CaO had decreased after the reaction. The percentage of CaO started to increase for 1.0 to 3.0 g of quicklime weight used. The situation occurred because of the coating of gypsum and iron hydroxide on the surface of the quicklime, which is also known as the armoring effect. At 1.0 g, the activity of quicklime with AMD was high compared to the activity of quicklime at 3.0 g. However, Figure 3 indicates that the percentage of Fe_2O_3 had increased after reaction as affected by the precipitation of iron in AMD by quicklime. The percentage of Fe_2O_3 had decreased after AMD reacted with 1.0 g of quicklime as initiated by the armoring effect. The highest Fe_2O_3 precipitated was at 1.0 g of quicklime. Figure 3 also shows the percentages of CuO and ZnO in AMD after the reaction. The highest percentages of CuO and ZnO precipitated were at 1.5 g of quicklime with $3.86 \pm 0.03 \%$ and $0.39 \pm 0.00 \%$. Figure 3 also shows the percentages of MnO, As_2O_3 and PbO that had increased after reaction with quicklime. This was due to the precipitation process that had occurred among these heavy metals. The highest precipitation of MnO, As_2O_3 and PbO had occurred at 2.0 g, 1.5 g and 1.0 g of quicklime.

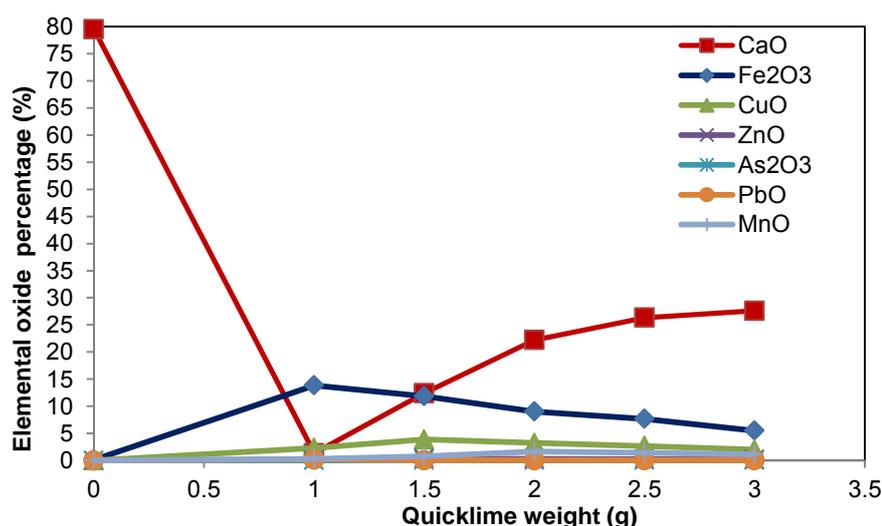


Figure 3: The percentage of CaO, Fe_2O_3 , CuO, ZnO, MnO, As_2O_3 and PbO in in quicklime before and after reaction

3.2 Water sample

3.2.1 pH values

Figure 4 shows the pH values from the five experiments that were carried out in the laboratory by using different weights of quicklime. The result shows that the pH values had increased in all experiments after the reaction. The highest pH obtained from the experiments was 10.22 ± 0.00 by using 3.0 g of quicklime at 60 min interval time. The value did not comply with the Environmental Quality Act 1974 for Standards A and B that was applied in Malaysia (Environmental Quality Act, 1974). For standards A and B, the pH values are 6.0 to 9.0 and 5.5 to 9.0. Standards A and B refer to the effluent of discharge water at the upstream and downstream of the catchment area. The best result obtained was 7.50 ± 0.00 by using 2.0 g of quicklime at 10 min interval time. The chosen value complied with Standards A and B.

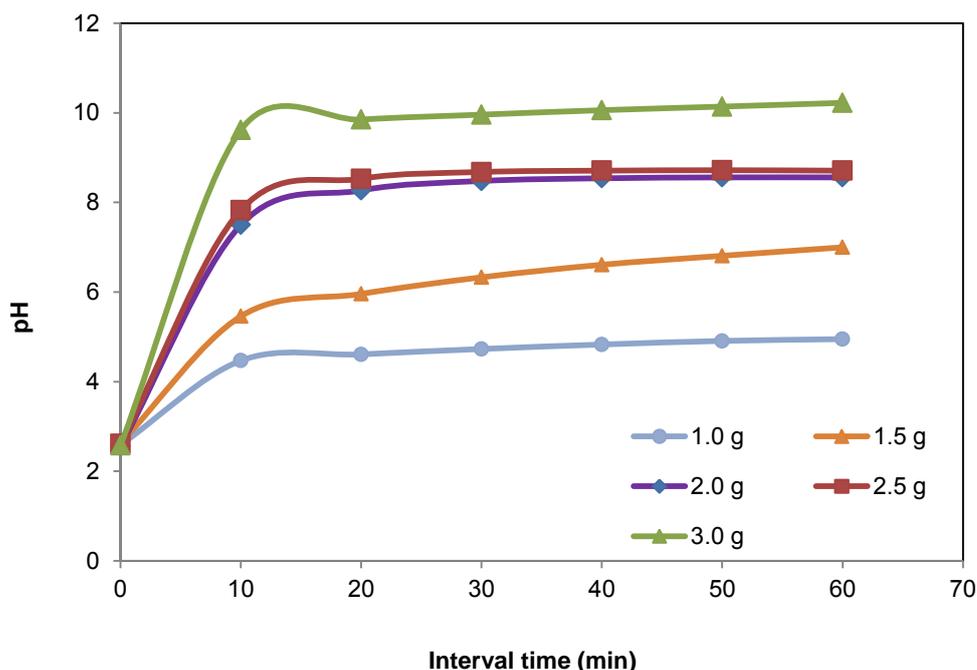


Figure 4: pH values of water sample before and after reaction

3.2.2 Sulphur and heavy metals content

Figures 5 and 6 show the sulphur and heavy metals content in water sample before and after the reaction. The result shows that the sulphur concentration in the water sample had decreased after the reaction. The decrease in sulphur in the water sample was caused by the formation of gypsum. The lowest concentration of sulphur obtained was 915.60 ± 2.69 mg/L at 1.0 g of quicklime.

Figure 6 indicates that heavy metals concentration such as arsenic, chromium and cadmium had decreased after the reaction. Only the concentration of cadmium at 1.0 g of quicklime with concentration of 0.08 ± 0.00 mg/L did not comply with both standards. Other concentrations of these heavy metals obtained after the reaction complied with the Environmental Quality Act 1974 either for both standards or only one standard. Standards A and B for arsenic, chromium (VI) and cadmium are 0.05 mg/L, 0.10 mg/L; 0.05 mg/L, 0.05 mg/L and 0.01 mg/L, 0.02 mg/L (Environmental Quality Act, 1974). The highest concentration of arsenic obtained after the reaction was 0.09 ± 0.01 at 1.0 g of quicklime that complied with Standard B only.

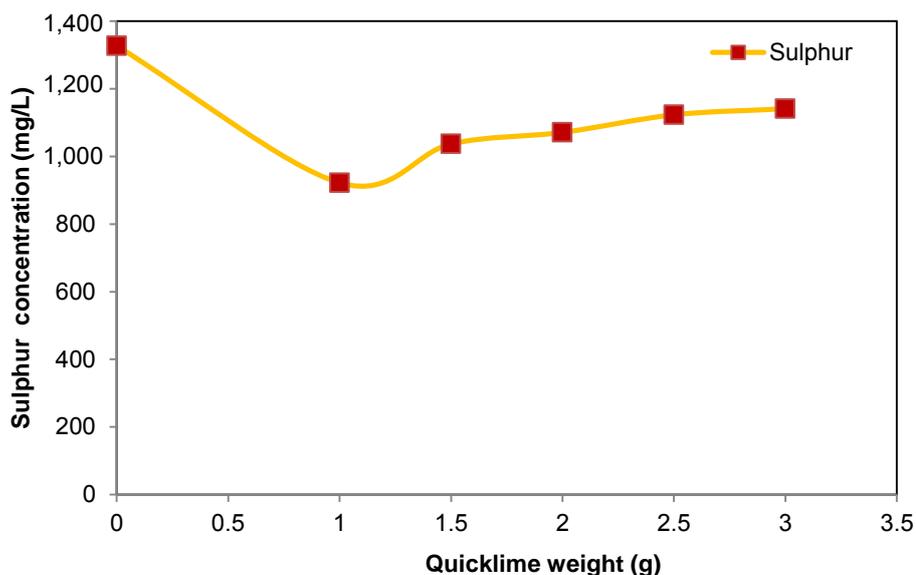


Figure 5: Sulphur content in water sample before and after reaction

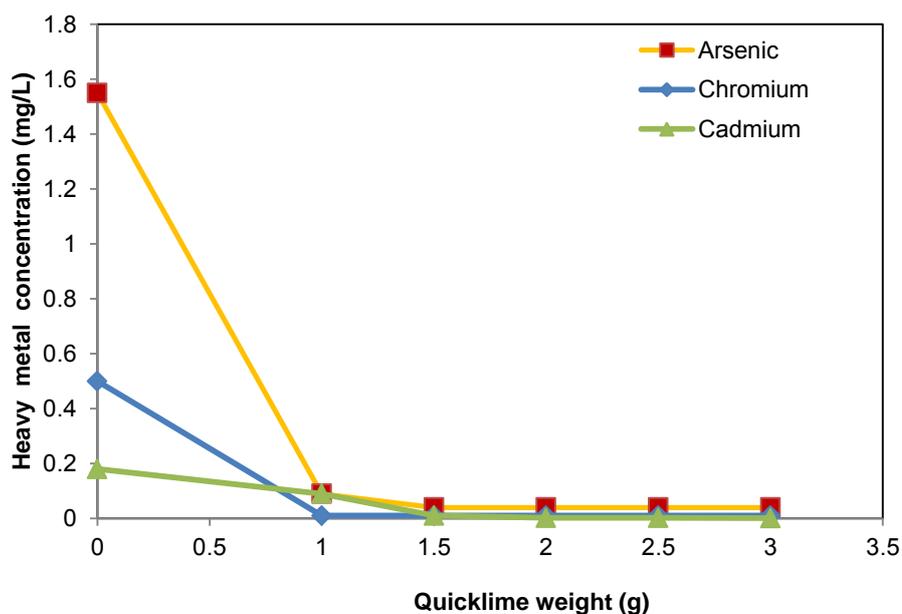


Figure 6: Heavy metals content in water sample before and after reaction

4. Conclusions

Based on the results obtained, quicklime is a suitable material to be used in AMD treatment. The best parameter chosen in this study was 2.0 g of quicklime because it can increase the pH value from 2.56 ± 0.00 to 7.50 ± 0.00 in 10 min compared to 1.5 g of quicklime to reach a pH value that complied with both Standards A and B in 30 min. For 1.0 g of quicklime to reach a pH value that complied with Standards A and B, it may take more than 60 min. For 2.5 g of quicklime, the time taken to reach a pH value that complied with both standards is the same with 2.0 g of quicklime, that is 10 min and for 3.0 g of quicklime the pH values obtained exceeded both standards. The 2.0 g of quicklime is the optimum parameter weight in treating AMD because the time and material used are minimum compared to the other weights in reaching the pH values that complied with Standards A and B. The 2.0 g of quicklime also has the capability to precipitate sulphur and reduce heavy metals concentration in AMD sample. The pH value and heavy metals concentration obtained such as arsenic, chromium and cadmium had complied with Standards A and B.

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