ASSESSMENT OF ULTRABASIC ROCK AND VOLCANIC TUFF FOR THE TREATMENT OF ACID MINE DRAINAGE

JOYCE KRISTY PRIMUS

FACULTY OF SCIENCE AND NATURAL RESOURCES
UNIVERSITI MALAYSIA SABAH

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JOYCE KRISTY PRIMUS

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DECLARATION

The materials in this thesis are original except quotations, excerpts, summaries and references, which have been duly acknowledge.

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Joyce Kristy Primus
PS2009-5532

CERTIFICATION

NAME	:	**JOYCE KRISTY PRIMUS**
MATRIC NO	:	**PS2009-5532**
TITLE	:	**ASSESSMENT OF ULTRABASIC ROCK AND VOLCANIC TUFF FOR THE TREATMENT OF ACID MINE DRAINAGE**
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1. **Supervisor**
   Prof. Dr. Marcus Jopony — Signature

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ABSTRACT

Metal-rich acid mine drainages (AMD) need to be treated appropriately prior to final discharge into the surrounding environment. In this study, the feasibility of using ultrabasic rock (UBR) and volcanic tuff (VT) as treatment materials to remove heavy metals from AMD was investigated. Initially, the efficacy of the materials were tested using acidic aqueous metal solutions (pH=2.5; metal concentration; 10 mg/L) at different contact time, particle size and solid-solution ratio. Subsequently the materials were tested using AMD samples collected from Mamut Copper Mine pit. The initial and final metal concentrations (Cu, Fe, Mn and Zn) and final pH were the main parameters analysed. The results shows that the metal removal from aqueous solutions by both materials s dependant on contact time, particle size and solid solution ratio. The highest efficiency was achieved at 12 hours and 16 hours contact time (for UBR and VT respectively), particle size <0.5 mm and solid-solution ratio 0.06 g/Ml. Under this condition, the removal of Cu, Fe, Mn and Zn by UBR is 100, 100, 71 and 96%, respectively, while by VT is less efficient at 74, 91, 36 and 52%, respectively. The efficiency of UBR is closely associated with the ability of the material to increase the pH of solution (and the final pH attained) and subsequent precipitation of the metals. By contract, metal removal by VT is more likely associate with adsorption. When tested on AMD samples (at optimum condition), UBR resulted in 100, 100, 67 and 99% removal of Cu, Fe, Mn and Zn, respectively from mine pit sample and 90, 97,6 and 69%, respectively, from Nasapang drain sample. Comparatively, VT resulted in 96, 100, 67 and 92% respectively; from mine pit sample and 60, 98, 12 and 11%, respectively, from Nasapang drain sample. While the efficiency of either material is dependent on the AMD sample, the efficiency of VT is lower than UBR and has relatively greater potential compared to VT as treatment material for removal of heavy metals from AMD.

ABSTRAK

PENILAIAN KEUPAYAAN BATUAN ULTRABES DAN TUF VOLKANIK UNTUK MERAWAT SALIRAN ASID LOMBONG

Saliran asid lombong (AMD) yang mengadugi logam yang tinggi perlu dirawat dengan sewajarnya sebelum dilepaskan ke alam sekitar. Dalam kajian ini, keupyaan menggunakan batuan ultrabes (UBR) dan tuff gunung berapi (VT) sebagai bahan rawatan untuk membuang logam berat dari AMD telah dikaji. Pada mulanya, keberkesanan bahan-bahan yang telah diuji menggunakan larutan asidik logam (pH = 2.5; kepekatan logam; 10 mg / L) pada masa sentuhan, saiz zarah dan nisbah pepejal- larutan yang berbeza. Selepas itu, bahan-bahan yang telah diuji menggunakan sampel AMD dari lombong timah Mamut. Kepekatan awal dan akhir logam (Cu, Fe, Mn dan Zn) serta pH adalah parameter utama yang dikaji. Keputusan menunjukkan bahawa penyingkiran logam daripada larutan akueus oleh kedua-dua bahan bergantung kepada masa sentuhan, saiz zarah dan larutan nisbah larutan-pepejal. Kecekapan tertinggi dicapai pada 12 jam dan 16 jam masa sentuhan (untuk UBR dan VT masing-masing), saiz zarah < 0.5 mm dan nisbah pepejal--larutan 0.06 g/mL. Dalam keadaan ini, penyingkiran Cu, Fe, Mn dan Zn oleh UBR adalah 100, 100, 71 dan 96% masing-masing manakala penyingkiran logam menggunakan VT adalah kurang berkesan pada 74, 91, 36 dan 52% masing-masing. manakala oleh VT adalah kurang berkesan iaitu pada 74, 91, 36 dan 52% masing-masing. Kecekapan UBR berkait rapat dengan kebolehan bahan untuk meningkatkan pH larutan (dan pH akhir dicapai) dan seterusnya logam. Oleh conrast, penyingkiran logam dengan VT adalah sekutu lebih cenderung dengan penjerapan. Apabila diuji ke atas sampel AMD (pada keadaan optimum), UBR menghasilkan 100, 100, 67 dan 99% daripada penyingkiran Cu, Fe, Mn dan Zn, masing-masing, manakala sampel lombong Mamut pada 90, 97,6 dan 69% masing-masing daripada sampel aliran Nasapang. Secara perbandingan, VT menghasilkan 96, 100, 67 dan 92% masing-masing, dari sampel sampel lombong Mamut; 60, 98, 12 dan 11% masing-masing daripada sampel aliran Nasapang. Walaupun kecekapan UBR dan VT bergantung kepada sampel saliran acid lombong. Kecekapan VT adalah lebih rendah daripada UBR dan mempunyai potensi yang lebih besar berbanding dengan VT sebagai bahan rawatan untuk penyingkiran logam berat daripada saliran acid lombong.

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ABBREVIATIONS AND SYMBOLS

AMD	-	Acid mine drainage
MCM	-	Mamut Copper Mine
ANP	-	Acid Neurtalizing Potential
NP	-	Neutraling Potential
Fe	-	Iron
Mn	-	Manganese
Al	-	Aluminium
Cu	-	Copper
Zn	-	Zinc
Pb	-	Lead
Cd	-	Cadmium
Ms	-	milliSiemen
L	-	Liter
mL	-	milliliter
M	-	Molarity
N	-	Normality
rpm	-	Rotation per minute
+	-	positive
-	-	negative
=	-	equal toa
➤	-	greater than
<	-	less than
≥	-	Same or greater than
≤	-	Same or lesser than
≈	-	Approximate
±	-	plus minus
°C	-	degree celcius
°	-	degree
ƛ	-	lambda
θ	-	theta

TDS	-	total disslove solids
SO_4^-	-	Sulphate ion
CO_3^{2-}	-	Carboante ion
OH-	-	hydroxide ion
$CaCO_3$	-	Calcium carbonate
H_2SO_4	-	Sulphuric acid
HCl	-	Hydrochloric acid
NaOH	-	Sodium carbonate
H2O2	-	Hydrogen peroxide
XRD	-	X-RAY diffraction
F-AAS	-	Flame atomic absorption spectrophotometer
kg	-	kilogram
g	-	gram
mg	-	milligram
nm	-	nanometer

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CHAPTER 1

INTRODUCTION

Mining is an act of tunneling and digging out of the ground to extract mineral resources such as gold, copper, and coal (Warhurst and Noronha, 1999). It is one of man's earlier activities that can be traced back into Paleolithic times, and it played an important role in the civilization.

Nowadays, the need of mined minerals has increased in both volume and variety, and thus mining has increased to meet the demands of the society (Bell and Donally, 2006). Mining of minerals contributes in terms of economic, but unfortunately it also effects the environment by forming acid mine drainage (AMD).

AMD is caused by series of chemical and biological reactions involving oxidation-reduction, hydrolysis, precipitation, dissolution reaction and microbial catalysis of iron sulphide, FeS_2 or pyrite (Bernier, 2004; Lal, 2006).

The major characteristics of AMD are high acidity, high metal concentrations, elevated sulphate level, excessive suspended solids, and/or siltation (Gaikward and Gupta, 2008). Typically, the pH of AMD ranges from 2 to 4, but some extreme sites such as Iron Mountain, California produced extremely acidic effluent with pH between 0.5 and 0.9 (Druschel *et al.*, 2004).

The low pH in AMD causes the metals from the ore to leach out, consequently polluting the receiving stream with heavy metals. The effect of AMD has taken its toll in many mining sites such as Iron Mountain California (Motsi *et al.*, 2009), Wheal Jane Mine in Cornwell, England (Johnson and Hallberg, 2005), Monday Creek Ohio and Ducktown Mining District, Tennessee (Lee *at al.*, 2002). Unfortunately, the problem with AMD also occurred in ex Copper Mine in Mamut, Ranau Sabah (Jopony and Murtedza, 1994).

The impact of AMD are evident from these mining sites, where the accumulation of metals found in the receiving river's sediments, and some bioaccumulation in plants and insects (Ali *et al*., 2004; David, 2003; Nieto *et al*., 2007; Balintova *et al.,* 2012; Svitok *et al*., 2014).

There were various AMD'S treatment methods. Precipitation of metal via neutralization (Carvotta *et al*., 2008; Bernier, 2005; Doye and Duchesne, 2003; Lee *et al*., 2002; Lovett, 1997; Maree, 1994) and adsorption of metals (Hala, 2013; Karatas, 2012; Can *et al*., 2009; Gaikward, 2008; Johnson and Jain, 2008; Jiang *et al*., 2006; Eglert and Rubio, 2005; Erdem, 2004) are the most common methods used in AMD treatment.

Most of the treatment sites suffer from some drawbacks such as high cost of treatment and high formation of sludge (Kalin *et al.,* 2005; Hammarstrom *et al*., 2003).

1.1 Background of Mamut Copper Mine

Mamut ex-copper mine located in Ranau, Sabah. The pit lake has a circle shape, with diameter approximately 1.0 km and 100 m depth. The mine started operation in 1975 and ceased operation in October 1999 due to low metals' prices and major landslide (Mine Reclaimation Corporation, 2010).

Currently, the problems emerging from Mamut ex-copper mine are: the discharge of AMD from the pit lake to the receiving stream, collapsing of unstable pit walls, and the impact on water and ecological system in the surrounding area of the mine (Mine Reclaimation Corporation, 2010).

MCM is drained by several rivers namely Mamut River Bambagan-Liwagu River, and Lohan River as shown in Figure 1.1. Study conducted by Ho*,* 2006 found out that among these rivers, Mamut River is most adversely affected by the AMD discharge from MCM.

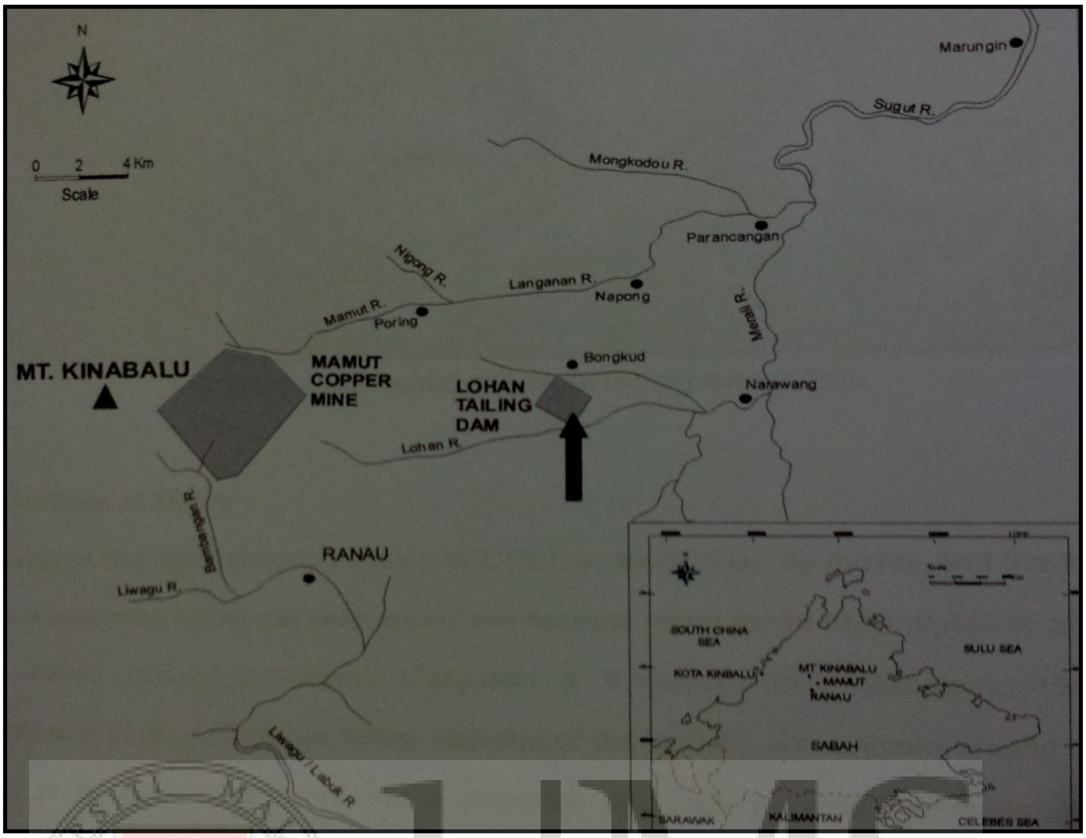

Figure 1.1: An Overview of Mamut Copper Mine (MCM) and the surrouding rivers.

Source : Jopony (1997)

There are several studies on treatment of AMD produced by MCM such as treatment using calcareous material i.e. calcareous sandstone and calcareous mudstone (Jopony and Tongkul, 2009), and plant i.e. *Typha angustifolia* (Lo and Saibeh, 2013).

Report by Mine Reclamation Corporation, 2010 on rehabilitation of ex-Mamut copper mine also suggested that neutralization capacity of serpentinite rock and other rocks should be evaluated.

1.2 Ultabasic rock and volcanic deposits distribution in Sabah

Serpentinized-peridotite is an ultrabasic rock that can be found abundantly in the MCM vicinity as shown in the Figure 1.2.

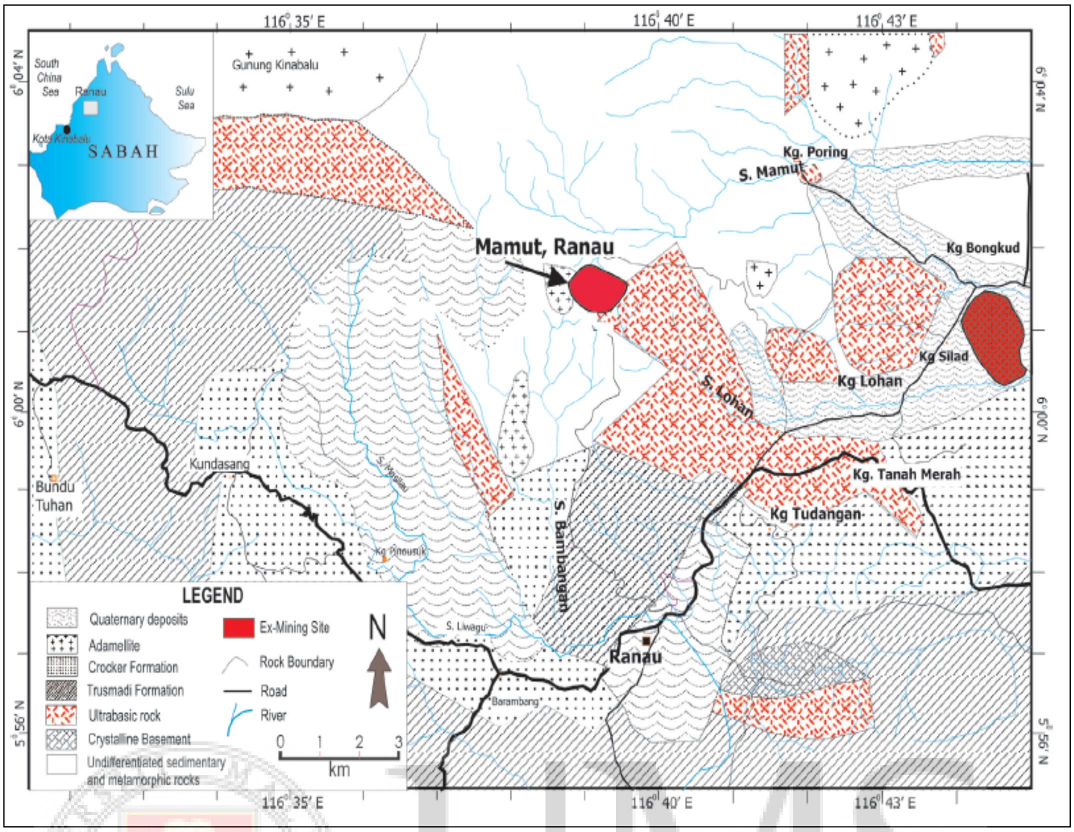

Figure 1.2: Distribution of Ultrabasic rock in the vicinity of MCM.

Source : Musta *et al.* (2013)

Volcanic minerals in Sabah can be found abundantly in the west cost of Sabah i.e. Tawau, Semporna, and Lahad Datu. The volcanic minerals distributions in Sabah are shown in Figure 1.3.