ACID MINE DRAINAGES AT MAMUT COPPER MINE, RANAU, SABAH

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ABSTRACT

ACID MINE DRAINAGES AT MAMUT COPPER MINE, RANAU, SABAH

Acid mine drainage (AMD) is an environmental problem of serious concern in most mining areas, particularly those with abandoned or closed mines. The existence of a closed mine in Sabah, namely Mamut Copper Mine (MCM), thereby indicates the potential occurrence of local AMD pollution. Scientific information on the AMD at the mine area is crucial towards understanding the impacts as well as the development of appropriate treatment measures. AMD discharge points at the mine (MCM) area were identified and samples (S1 to S12) were taken periodically from up to 12 sites and analyzed for selected parameters namely pH, E_C, TDS, total acidity/alkalinity, sulfate and dissolved metals (Fe, Al, Mn, Cu, Zn, Cd and Cr) according to Standard Method. Water samples from selected river in the vicinity of the mine were also collected and analyzed for similar water quality parameters. The buffering characteristics of the AMD samples were also evaluated by potentiometric titration with NaOH solution. Additionally, the effect of neutralization on dissolved metal (Fe, Al, Mn, Cu and Zn) concentration of the AMD was investigated. The results showed that the AMDs at MCM have varying characteristics, with low pH(2.90-3.75), high total acidity(176-1697 mg $CaCO_3$/L), high TDS(302-2673 mg/L), high E_C(606-5370 μS/cm), sulfate(292-2808 mg/L) and elevated concentrations of dissolved Fe(0.12-7.13 mg/L), Al(12.24-192.14 mg/L), Mn(2.75-79.87 mg/L), Cu(2.02-47.03 mg/L), Zn(0.35-25.42 mg/L) and relatively low concentration of Cd(0.001-0.127 mg/L) and Cr(0.007-0.045 mg/L). The values of the selected parameters showed variation according to AMD sample and to some extent, sampling time. Amongst the various parameters, high correlations exist between total acidity and dissolved Al, TDS (or E_C) and sulfate, Al and Zn, Al and Cu, and Zn and Cu. The total acidity is dominated (67-93%) by mineral acidity while the rest is attributed to free acidity. Based on its total acidity, the AMDs comprised of high strength, medium strength and low strength AMD. Comparatively, the characteristics of river water samples are as follows: pH(4.57-8.12), alkalinity(1.0-58.0 mg $CaCO_3$/L), E_C(63.8-652.0 μS/cm), TDS(31.7-324.5 mg/L), dissolved sulfate(0.21-337.95 mg/L), dissolved metals Fe(<0.02 mg/L), Al(<0.1-3.43 mg/L), Mn(<0.01-4.07 mg/L), Cu(<0.1-1.11 mg/L), Zn(<0.1-0.6 mg/L), Cd(<0.01 mg/L) and Cr(<0.01 mg/L). Only one river, namely Mamut River, (R5) showed strong evidences of AMD pollution as shown by its acidic pH, low alkalinity, and relatively high TDS, E_C, sulfate, Mn, Al, Cu and Zn. The titration data clearly showed that the amount of base required to increase the pH of the AMD up to pH ≥ 7.0 is strongly dependent (R^2=0.9996) on the total acidity (or the strength) of the sample: S8>S7>S5>S4>S11>S6>S1~S2~S3>S10>S12>S9. The higher is the total acidity, the greater is the amount of base required for neutralization. The increase in pH during neutralization resulted in the decrease of dissolved Fe, Al, Mn, Cu and Zn concentrations. This trend was dependent on the type of metal but independent on the type of AMD. Fe was effectively removed from solution at pH~4.0 while Al at pH~5.0. By contrast, Cu, Zn and Mn were effectively removed at pH~7.0, pH~8.0 and pH~10.0, respectively. The removal of the metals is attributed to precipitation reaction and the amount of precipitate formed increases with increase in pH, and total acidity of the AMD. Overall, the physicochemical characteristics of AMDs at MCM are generally similar to AMDs elsewhere. Nevertheless, due to its strong ability to buffer pH and greater precipitate production, the high strength AMDs from two sites (S8 and S7) can potentially pose more severe impacts to the receiving surface water while its treatment can be more complicated compared to other AMDs in the area.

ABSTRAK

Saliran asid lombong (AMD) merupakan suatu masalah alam sekitar yang serius di kebanyakan kawasan perlombongan terutamanya bagi lombong yang telah ditutup atau ditinggalkan. Sehubungan itu, kewujudan lombong yang telah ditutup di Sabah, iaitu Lombong Tembaga Mamut (MCM) memberi petunjuk potensi pencemaran AMD setempat. Maklumat saintifik mengenai AMD di MCM adalah penting untuk memahami impaknya serta untuk penyediaan kaedah rawatan yang sesuai. Lokasi pelepasan AMD di MCM telah dikenalpasti dan sampel (S1-S12) telah diperoleh secara berkala dari 12 tapak. Setiap sampel telah dianalisis untuk parameter pH, E_C, TDS, keasidan jumlah/alkaliniti, sulfat and logam terlarut (Fe, Al, Mn, Cu, Zn, Cd dan Cr) mengikut kaedah piawai. Sampel air dari sungai terpilih berdekatan kawasan lombong juga diperoleh dan dianalisis untuk parameter kualiti air yang sama. Ciri penimbalan sampel AMD ditentukan secara titratan potensiometik dengan larutan NaOH. Kesan peneutralan terhadap kepekatan logam (Fe, Al, Mn, Cu dan Zn) dalam sampel AMD juga dikaji. Hasil kajian menunjukkan AMD di MCM mempunyai ciri yang berbeza, dengan pH yang rendah (2.90-3.75), keasidan jumlah yang tinggi (176-1697 mg $CaCO_3$/L), TDS tinggi (302-2673 mg/L), E_C tinggi (606-5370 µS/cm), sulfat tinggi (292-2808 mg/L) and kepekatan tinggi bagi Fe(0.12-7.13 mg/L), Al(12.24-192.14 mg/L), Mn(2.75-79.87 mg/L), Cu(2.02-47.03 mg/L), Zn(0.35-25.42 mg/L), dan kepekatan rendah bagi Cd(0.001-0.127 mg/L) dan Cr(0.007-0.045 mg/L). Nilai-nilai parameter ini menunjukkan variasi antara sampel AMD serta masa persampelan. Di antara parameter di atas, korelasi yang baik wujud di antara keasidan jumlah dan Al, TDS (atau E_C) dan sulfat, Al dan Zn, Al dan Cu, dan Zn dan Cu. Keasidan jumlah sampel AMD didominasikan oleh keasidan mineral (67-93%) dan selebihnya disumbangkan oleh keasidan bebas. Berdasarkan nilai keasidan jumlah, AMD di MCM mempunyai kekuatan berbeza iaitu AMD kuat, AMD sederhana, dan AMD lemah. Secara perbandingannya, ciri-ciri sampel air sungai adalah seperti berikut: pH(4.57-8.12), alkaliniti(1.0-58.0 mg $CaCO_3$/L), E_C(63.8-652 µS/cm), TDS(31.7-324.5 mg/L), sulfat(0.21-337.95 mg/L), Fe(<0.02 mg/L), Al(<0.1-3.43 mg/L), Mn(<0.01-4.07 mg/L), Cu(<0.1-1.11 mg/L), Zn(<0.1-0.6 mg/L), Cd(<0.01 mg/L) dan Cr(<0.01 mg/L). Hanya sebatang sungai, iaitu Sungai Mamut (R5) menunjukkan bukti kuat kewujudan pencemaran AMD iaitu pH asid, alkaliniti rendah dan TDS, E_C, sulfat, Mn, Al, Cu dan Zn yang tinggi. Data titratan menunjukkan dengan jelas bahawa amaun bahan bes yang diperlukan untuk meningkatkan pH sampel AMD ke pH≥7.0 bergantung kuat (R^2=0.9996) kepada keasidan jumlah (atau kekuatan) sampel: S8>S7>S5>S4>S11>S6>S1~S2~S3>S10>S12>S9. Semakin tinggi nilai keasidan jumlah, semakin banyak amaun bes diperlukan untuk peneutralan. Peningkatan pH semasa proses peneutralan menghasilkan penurunan kepekatan logam Fe, Al, Mn, Cu dan Zn. Tren ini bergantung kepada jenis logam tetapi tidak bergantung kepada jenis atau kekuatan AMD. Logam Fe, Al, Cu, Zn dan masing-masing dapat disingkirkan dengan efektif dari larutan pada pH~4.0, pH~5.0, pH~7.0, pH~8.0 dan pH~10.0. Penyingkiran logam dari larutan dikaitkan dengan tindakbalas pemendakan, dan amaun mendakan yang terhasil meningkat dengan peningkatan pH serta nilai keasidan jumlah sampel AMD. Pada keseluruhannya, ciri-ciri fizikokimia AMD di MCM adalah lebih kurang sama dengan AMD di tempat lain. Namun demikian, atas sebab keupayaan tinggi untuk menimbal pH serta penghasilan mendakan yang lebih banyak, AMD kuat di dua lokasi di MCM (S8 dan S7) berpotensi untuk memberi impak negatif yang ketara kepada sungai yang menerima inputnya manakala rawatannya boleh lebih rumit berbanding dengan AMD lain di kawasan tersebut.

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ABBREVIATIONS AND SYMBOLS

AAS	Atomic absorption spectrophotometer
AMD	Acid mine drainage
MCM	Mamut Copper Mine
E_C	Electrical conductivity
Eq.	Equation
+	positive
-	negative
=	equal
~	nearly to/about
<	less than
>	more than
≥	more than or equal
≤	less than or equal
%	percent
^{0}	degree
°C	degrees Celsius
K_{sp}	solubility product
λ	wavelength
M	molar
sec^{-1}	per second
min^{-1}	per minute
atm^{-1}	per atmosphere
mL	milliliter

L	Litre
N	Normality
mg/L	milligram per liter
mg $CaCO_3$/L	milligram calcium carbonate per liter
nm	nanometer
µS/cm	microsiemens per centimeter
Fe	Iron
Al	Aluminium
$Al(OH)_2$	Aluminium hydroxides
Mn	Manganese
$Mn(OH)_2$	Manganese hydroxides
Cu	Copper
$Cu(OH)_2$	Copper hydroxides
Zn	Zinc
$Zn(OH)_2$	Zinc hydroxides
Cd	Cadmium
Cr	Chromium
TDS	Total dissolved solids
SO_4	sulfate
CO_3^{2-}	Carbonate
HCO_3^-	Bicarbonate
H_2CO_3	Carbonic acid
H^+	proton
OH^-	Hydroxide
$CaCO_3$	Calcium carbonate

H_2SO_4	Sulphuric acid
HCl	Hydrochloric acid
NaOH	Sodium hydroxide
H_2O_2	Hydrogen peroxide

LIST OF APPENDIX