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Water quality monitoring for heavy metal contamination associated with acid mine drainage at abandoned and active mining sites in Pahang

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Abstract

Acid mine drainage is typically resulted from mining activities through mineral interactions with atmospheric oxygen and water. This study investigates the heavy metal concentrations and also occurrence of acid mine drainage (AMD) in active and abandoned mining sites in Pahang. Three sites were investigated within Kuantan (active bauxite mining), Kuala Lipis (active iron mining) and Bukit Ibam (abandoned iron mine). *In-situ* parameters were measured and surface water and sediment were also collected and analysed for heavy metals. Based on the investigations, there are sites that have acidic *pH* values indicating the occurrence of acid mine drainage (AMD) which has been a major concern of this study. Based on the heavy metal analysis, the concentrations of Fe, Mn, Al and Pb in water and sediment of few sites have exceeded the allowable standard limits for treated and raw water by the Malaysian Ministry of Health. The study concludes that there is an urgent need for appropriate treatment of the affected sites to prevent further environmental deterioration.

Keywords: heavy metal concentrations, water quality monitoring, abandoned mine, active mine, acid mine drainage

INTRODUCTION

Pahang has many kinds of mineral resources that have been actively mined and according to the Malaysian Mining Industry report by Minerals and Geoscience Department Malaysia, Pahang remained as the top producer for most minerals in the country. As a result of heavy mining in this state, there are several mines that are now abandoned without proper manner of closure due to poor enforcement of previous mining regulations. Currently, Environmental Quality Act (1994) stated the regulations for mining activities in Malaysia but still the enforcement is very low. Therefore, there are high possibilities that the heavy metal toxins could penetrate into the underground water and cause water pollution. Hence, the objective of this research is to investigate the heavy metal concentrations in both abandoned and active mining sites in Pahang.

Problem that could arise for a long time period due to improper of mining management is acid mine drainage (AMD). AMD is known as significant pollution problem produced from both active and abandoned mine (Diz et al., 2006) which give serious impact to the hydrological cycle. AMD is produced by the exposure of sulphide minerals, resulting in production of acid making the *pH* of the water to reduce hence elevated the concentrations of metals and sulphate. AMD pollution may cause severe impacts on biological systems in long term period (Luptakova and Macingova, 2012). Thus, this study also investigates the AMD phenomenon at several locations in Pahang.

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MATERIALS AND METHODS

Study site and field sampling

The study was conducted at two active mines namely Kuantan and Kuala Lipis and one abandoned mine namely Bukit Ibam in Pahang as presented in figure 1. *In situ* parameters such as total dissolved solid (TDS), *pH*, dissolved oxygen and conductivity were measured at all stations. The portable meter which is an ultrameter II 6PFC Myron L was immersed in the surface water on-site and readings of various parameters were recorded. Surface water and sediment samples were collected at these sites and were taken back to laboratories for heavy metal analysis.

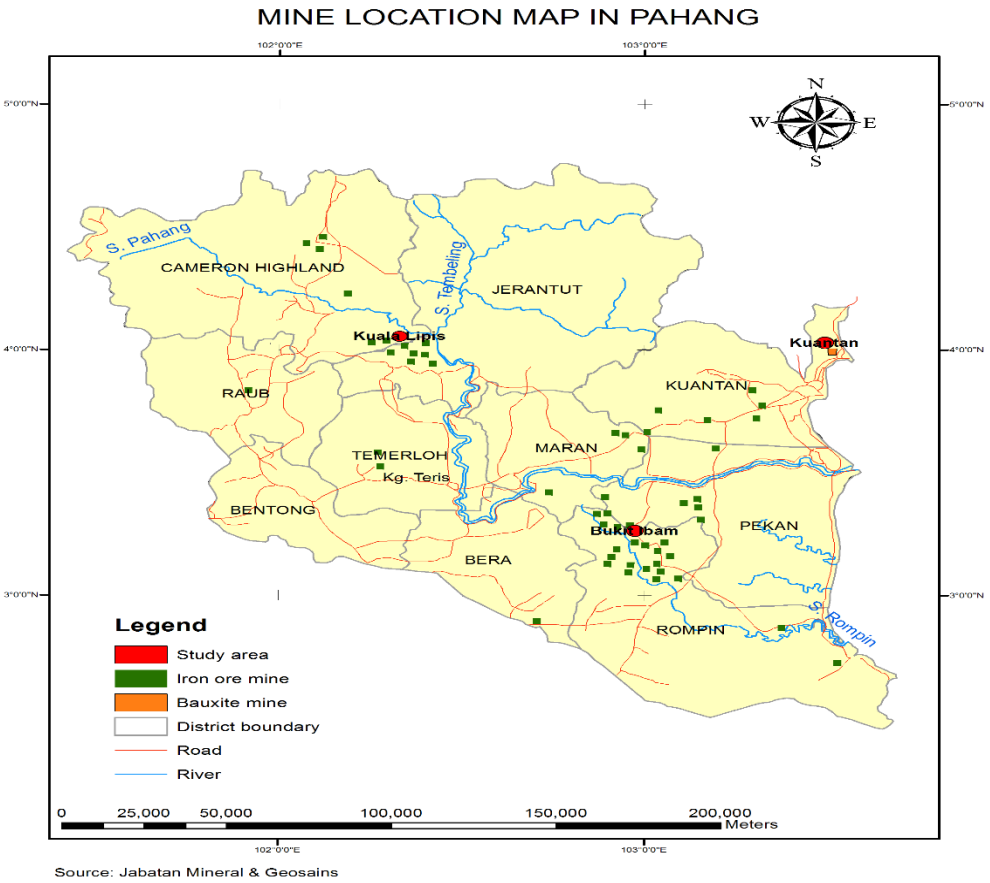

Figure 1. Map of mining study sites of Bukit Ibam, Kuala Lipis and Kuantan. (Mineral and Geoscience Department Malaysia, 2014).

Laboratory analysis

For heavy metal analysis, water samples were preserved by adding a few drops of nitric acid for 50ml of water samples. The samples were filtered upon arrival in the laboratory. Filtered water samples were analysed using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). In sediment analysis, aqua regia method of ratio 1:3 was used. First, soil were oven dried at 110^{o}Cfor 2 hours and pulverized into powder using agate-mortar. Then, 1.0g sample were pre-digested using ratio 1:3 of nitric acid and hydrochloric acid for a night. Then, the samples were digested at increasing temperatures until it reach 140^{o}C and were analysed using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES).

RESULTS AND DISCUSSION

Physico-Chemical Paramaters in Water

In Pantai Balok Kuantan, results of *in situ* parameter measurements are presented in table 1. Station 1 (S1) was located at the operating mining site. Station 2 (S2) was at the drain of an industrial area near to the mining site. Station 3 (S3) was at a river located near the transportation area of bauxite. Station 4 (S4) was located at an estuary of the river and Pantai Balok. Lastly, station 5 (S5) was located at a river near to the stockpile of the bauxite. The *pH* values show that Pantai Balok mining sites were slightly acidic to neutral. Although the colour of the water samples was red due to the bauxite, the pH does not show any formation of acid mine drainage.

For Bukit Ibam, the result for in situ parameter measurements are presented in the same table. The *pH* values show that the abandoned mine are not acidic with the *pH* value is 6.99. The *pH* value recorded at this site would give an indication that there is no acid mine drainage at the area. The values are similar at Kuala Lipis active mine where the *pH* value is 7.9. The values also shown that the *pH* are neutral. The electrical conductivity however in all three places were very high. High electrical conductivity shows presence of mineral contents in the sediment and water, subsequently releasing inorganic substances as explained by Radojevic et al. (2007).

As going further investigation on Kuantan sampling site, figure 2 show the relationship of conductivity and total dissolved solid in all Kuantan stations. The figure showed that as conductivity is low, the total dissolved solid is low and vice versa. High conductivity value in Kuantan mining area maybe due to the presence of mineral contents in the sediment and water, releasing inorganic substances (Radojevic et al., 2007). Conductivity value are considered to represent the concentration of total dissolved solids (TDS). TDS is the concentration of dissolved solids present in water which is made up of inorganic salts, and also organic matter. TDS can be an indicator for harmful contaminants such as iron, manganese, sulfate, bromide and arsenic to be present in water. Ashraf et al. (2010) indicates that high EC values in the active sand mining area may be due to the presence of mineral contents in the sediment and water, subsequently releasing inorganic substances. It was found that there is a significant relationship between EC and TDS in water (p-value < 0.05).

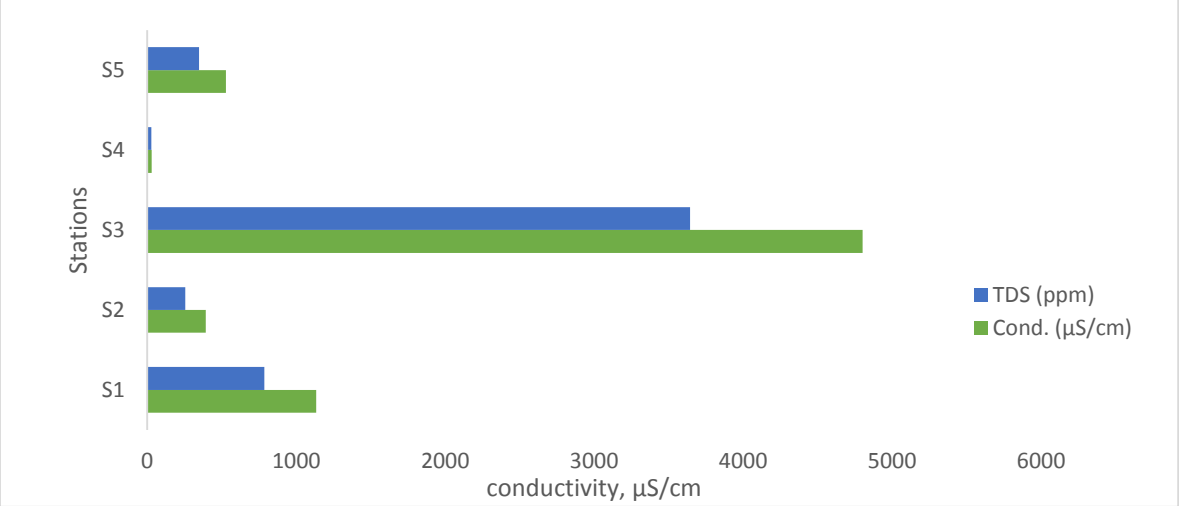

Figure 2. The relationship between EC and TDS in water for Kuantan sampling stations.

Heavy metal analysis

Heavy metal concentrations for Bukit Ibam, Kuala Lipis and Kuantan were analysed and shown in table 1. The result shown in figure 3 is the heavy metal concentration in Kuantan sampling stations. The concentration values are compared with the parameter limits of effluents of Mininster of Health raw water standards (2009). This standards were used

besides the DOE standards is because the raw water standards by MOH consist of all the parameters with the maximum limitation permitted before entering the water treatment plant whereas the DOE standards are the classification from thus parameter result valued basis from certain maximum permissible concentration or limits and no classification is needed in this study. Based on the concentration values, most of the heavy metal concentrations are below the MOH standards. However there are stations that show high heavy metals in iron (Fe), manganese (Mn), lead (Pb) and aluminium (Al). In Kuala Lipis, the value of iron in the mining site has exceed the standard which is 1.299 mg/L. Overload of iron in the human body is dangerous as it can lead to diseases such as hemochromatosis, a severe disease that can damage organ bodies. Another heavy metal that has exceeded the MOH raw water standard is manganese (Mn). The highest value of manganese is 4.156 mg/L which is located at a river just opposite the stockpile. This is because there is drainage system along the stockpile and as it rains, the red mud will discharge to the river, making the river full with bauxite that contain manganese in it. This heavy metal are also present in the sediment sample and can be concluded that there is manganese in the bauxite residue. Manganese can give harmful effect to human as it can cause infertility, cancer, mental confusion and also reduced immune function (Blaurock-Bausch, 1997).

The concentration values are different between water and sediment because of the high density of the heavy metals which accumulated to the water bed. From the results of both water and sediment heavy metal concentrations above, it is noticeable that the concentration of iron and manganese in sediment increase whenever the *pH* in water decrease. This may be the result of the *pH* changes in water; when *pH* has decrease the solubility of the Fe and Mn tend to be lower and become insoluble thus accumulating in the sediment.

Table 1. Physico chemical parameters and heavy metal analysis at all stations.

Location	pH	DO (mg/L)	Cond. (µS/cm)	TDS (ppm)	Fe	Mn	Al	Pb
					(mg/L)			
Kuantan (Active bauxite mining)								
S1-Bukit Goh	5.95	7.89	1134	786.2	0.125	0.05	0.181	0.002
S2-Industrial discharge (Port)	6.44	6.4	392	254.5	0.177	1.646	0.17	0.009
S3- Industrial discharge II (Port)	6.91	5.6	4803	3645	0.392	0.756	0.099	0.14
S4-Balok estuary	7.13	3.7	28.2	27.05	0.392	0.756	0.054	0.014
S5-Stockpile (Port)	7.13	2.67	528.7	348.2	1.574	4.156	0.826	0.012
Kuala Lipis (active iron ore mining)								
S1-Kuala Lipis discharge	7.9	3.76	559.5	369.5	1.299	0.297	0.13	<L.O.D
Bukit Ibam (abandoned iron ore mine)								
S1- Bukit Ibam (river)	6.99	5.31	200.95	127.9	0.104	1.027	0.345	<L.O.D
MOH (2009) untreated/ raw water	5.5-9	na	na	1500	1	1	na	0.2

In contrast, the concentration of such metals in water, as *pH* is getting higher, the heavy metal concentrations will be lower. Technically in Kuantan, sediment analysis at station 1 shows that it contain high value of manganese and zinc. This proves that there is no proper treatment going on in the mining site as the sediment is highly polluted with heavy metals. Station 2 is also highly polluted with iron, manganese and zinc. Station 2 is located at the drainage system at an industrial area where the transportation of bauxite are operated. From here, it can be proven that even the drainage system are polluted with heavy metals where further action need to be taken. The concentration values are also high at station 4 (the

estuary of the river and Pantai Balok). Lastly, station 5 was located at a river near to the stockpile of the bauxite and the result shows that there is highly polluted with iron, manganese and zinc. The total metal concentration of heavy metals is useful in identifying the pollution source and the potential contamination (Ashraf et al., 2010).

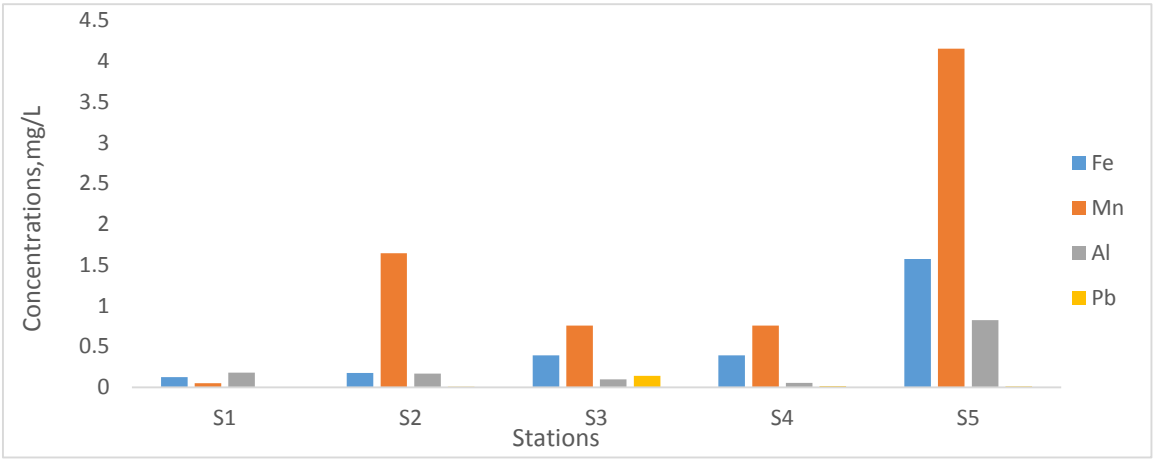

Figure 3. Heavy metal concentrations in water for Kuantan sampling stations

CONCLUSIONS

The following conclusions can be drawn from the study:

- The study of abandoned and active mines in Pahang revealed that the water quality is in caution state and need constant monitoring. The *pH* showed that there is no acid mine drainage happening at all site locations. At some localities, limestone formation is a good neutraliser to prevent acid mine formation.
- Other than that, exposed mine wastes and tailing could be one of the factor why there is no acid mine drainage. Despite that, factor of age also could be considered as the formation is too new to build up acid mine drainage.
- However, as further investigation are done in Kuantan Pahang, the sediment analysis show that the sampling locations at Kuantan are highly polluted with iron and manganese. Hence it can be concluded that there is no proper treatment and precautions are made there and further actions need to be taken.
- Therefore, immediate study and care must be carried out as soon as possible.

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