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An Analysis of Heavy Metals in Lakes of Former Tin Mining Sites in the City of Ipoh, Perak, Malaysia

Mohmadisa Hashim[1], Wee Fhei Shiang[1], Zahid Mat Said[2], Nasir Nayan[1], Hanifah Mahat[1] & Yazid Saleh[1]

[1]Department of Geography & Environment, Faculty of Human Sciences, [2]Department of Biology, Faculty of Sciences & Mathematics, Universiti Pendidikan Sultan Idris, 35900 Tanjong Malim, Perak, Malaysia

Email: mohmadisa@fsk.upsi.edu.my

Abstract

The purpose of this study was to evaluate the water quality, particularly the heavy metal parameters, at five former tin mining sites that have been used as recreational lakes: Lake Lahat, Lake Kg. Temiang, Lake Kg. Tengku Hussein, Lake Gunung Lang and Lake Taman Indah. The heavy metal parameters tested were arsenic (As), lead (Pb), copper (Cu) and zinc (Zn). The method of testing used laboratory analyses and water sample observations for 12 months between September 2015 and August 2016. Heavy metal parameters were compared with the standards published by the Department of Environment (DOE) and the Ministry of Health (MOH) to determine the quality of the lakes water. The results of the analyses showed that all of the lakes contained high concentrations of Pb compared to other metals. The amount of Pb detected in the lakes from highest to lowest concentration was Lake Kg. Tengku Hussein (1.08 mg/l), Lake Kg. Temiang (0.99 mg/l), Lake Lahat (0.96 mg/l), Lake Taman Indah (0.78 mg/l) and Lake Gunung Lang (0.60 mg/l). The metal readings of As, Cu and Zn metals were below the standards set by the DOE and MOH. Periodic research and monitoring of water quality by the Ipoh City Council (MBI) should be given attention so that the quality of the lake water, especially in relation to heavy metal elements, is under control which makes recreational water activities involving water contact are safe for the visitors'.

Keywords: Water Quality, Ex-Mining, Reclamation, Heavy Metal, Ipoh City

Introduction

The Kinta Valley, located in Perak, is well-known for its tin mining activities, especially in 1848 after a large amount of tin ore was found. The growth of this mining sector was also influenced by factors of industrial revolution development, Chinese labour incursions, capitalisation by foreign investors, the introduction of dredges and the development of the communication system. This mining boom indirectly propelled the development of Ipoh, as the town is a source of tin ore to this day. Growth in the mining sector in Ipoh was not sustainable

following the recession of the world economy between 1927 and 1930, which further affected the sale of tin ore. This loss resulted in repercussions to tin entrepreneurs, who were forced to close the mine area (Ahmad, 2004; Yap, 2007).

The remains of the Kinta Valley mine sites were later repurposed as a water recreation sites. This situation provided benefits to developers as well as to locals because the area could be used for recreation and development. Regarding water recreation activities, the concentration of heavy metals in the water is particularly concerning. Heavy metals are naturally present in water bodies at low concentrations; construction of the mining sector indirectly increased the concentration of heavy metals in water (Abdullah, 2012; Alina et al., 2012; Ashraf et al., 2010; Younger, 2001). First-time pollution in an environment can pollute the entire ecosystem of the environment (Harrison et al., 2009; Spitz & Trudinger, 2008). Human exposure to heavy metals either through water or air may adversely affect health (Abdullah, 2012; Duruibe et al., 2007; Hasmah, 2011; Ramlan, 1998).

Therefore, research on the quality of lake water is very important before any development can takes place. The development of lakes without careful planning not only affects the lake ecosystem, but also threatens the quality of life of the locals. This study focuses on four heavy metals—arsenic (As), copper (Cu), lead (Pb) and zinc (Zn) - that are among the most common heavy metals produced by tin mining activity (Ashraf et al., 2013). Asbestos and Pb are widely distributed across the water environment and have no benefit to humans (Draghici et al., 2010; Vieira et al., 2011). Additionally, these two chemicals are dangerous not only to human health, but also to animals even at low concentrations (Alina et al., 2012; Gonzales & Armenta, 2008; Jomova & Valko, 2011; Tokar et al., 2011). Research on the heavy metals in ex-mining lakes can prove whether a lake in question is suitable for development as a water recreation area.

Area and Methodology

This study focuses on five former lakes in Ipoh: Gunung Lang, Taman Indah, Kg. Temiang, Lahat and Kg. Tengku Hussein. The lakes were chosen because they will be developed as a water recreation area. The selection of Lake Gunung Lang, which has been developed as a recreational area, was used as a guide to the monitoring of water quality for other lakes, including the testing of heavy metals. Figure 1 shows the location and sampling stations of all of the lakes. A total of five sampling stations were selected for each lake, with the exception of Lake Kg. Tengku Hussein, which only had three sampling stations due to environmental constraints. The selections of the locations of the sampling stations were randomly based on the different types of land use in the proximity of the lakes which can directly contribute to the changes in water quality. Table 1 shows the sizes and locations of each lake. Sampling was carried out for 12 months from September 2015 to August 2016. The 12-month sampling period was chosen with the aim of identifying water-quality trends, the suitability of recreational activities and the occurrence of any activities that contribute to the pollution of the lake.

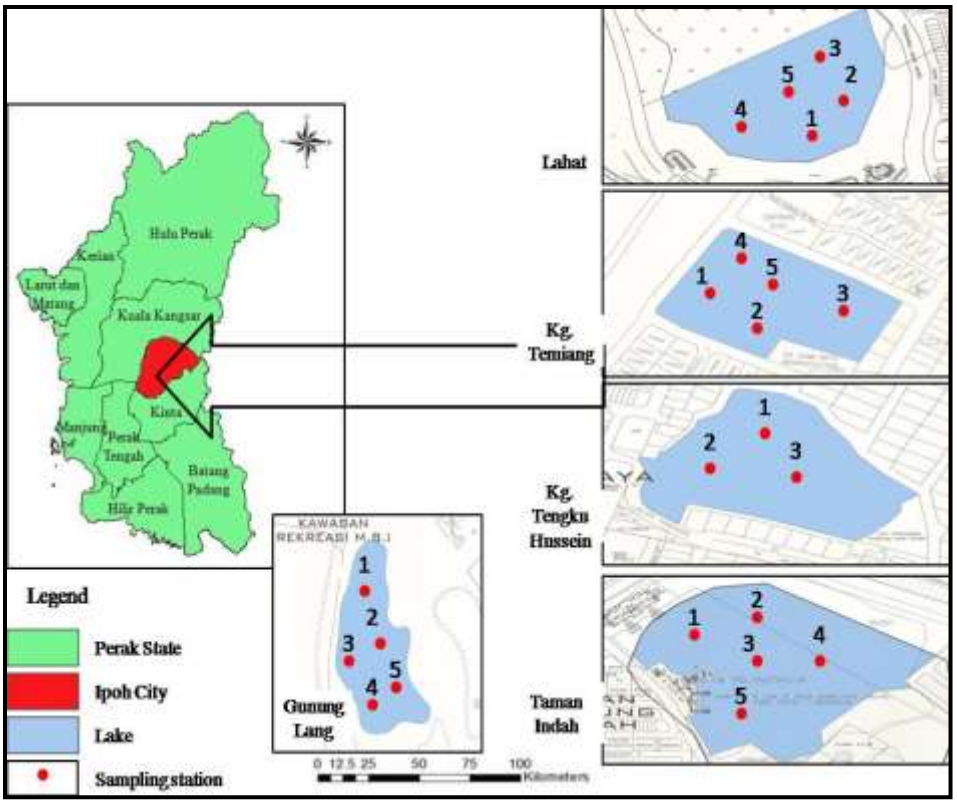

Figure 1. Location of lakes in Ipoh and sampling stations.

Table 1
Lake area and position in Ipoh.

Sampling location	Area (km^2)	Latitude Longitude
Lahat	105.90	N4º54'48.21", E101º03'69.61"
Taman Indah	102.81	N4º65'80.61", E101º16'31.84"
Gunung Lang	46.72	N4º62'58.47", E101º08'91.01"
Kg. Tengku Hussein	31.78	N4º61'41.50", E101º06'08.87"
Kg. Temiang	18.03	N4º57'94.59", E101º07'12.12"

Laboratory analyses were carried out to analyse the concentration of As, Cu, Pb and Zn. Field water sampling involved several procedures to ensure that no errors were encountered during the experimental process in the laboratory. For this purpose, water samples were taken at a depth of 1 meter from the surface of the water. This is in line with the Environmental Analysis of Quebec (2009) guide, which states that water samples to be analysed for their chemical properties should be taken at a depth of more than 30 cm from the surface of the water. Next, the water was labelled with the number and name of the study station. During the process of filling the water in the bottle, it was important to ensure that the bottle was free of any air bubbles. Finally, then the bottle was wrapped with aluminium paper and placed in a cool box containing ice for curing purposes. The preservation procedure used is described in APHA (2012).

The heavy metal test procedure was guided by APHA (2012), and it involved the use of standard chemical solutions of 1 ppm, 2 ppm, 3 ppm, 4 ppm and 5 ppm. Water samples were poured into the test tube and then placed in the Agilent 700 Series inductively-coupled plasma

optical emission spectrometers (ICP-OES). The process of detecting the presence of heavy metals involved combustion using argon gas. The heavy metals concentration is detected further by displayed on computer screen. Heavy metal readings were recorded and compared to Water Quality Index (WQI), Department of Environment (DOE), Malaysia and Ministry of Health (MOH) standards to determine the status of water quality either in a clean or polluted state. The detection of these heavy metals provided guidance as to whether the lake area was suitable for water recreation or otherwise.

Result and Discussion

Average heavy metal observations

The average analysis of the study samples are shown in Table 2. In summary, all of the lakes were polluted with Pb. The presence of this metal in water was incompatible with DOE and MOH standards. These results indicate that the lake that will be developed as a water recreation site still needs to be monitored in terms of water quality. For As, the relative readings recorded also did not meet MOH standards; however, they still meet the minimum requirements set by the DOE. Cu concentrations exceeded MOH standards for all lakes, and exceeded DOE standards with the exception of Lake Lahat. Zn was not detected in Lake Lahat and Kg. Temiang; the presence of the metal in other lakes was in accordance with DOE and MOH standards.

Table 2
Average concentration of heavy metal observations.

Lake	Heavy Metal (mg/l)			
	Arsenic (As)	Lead (Pb)	Copper (Cu)	Zinc (Zn)
Lahat	0.05	0.96	0.03	ND
Kg. Temiang	0.02	0.99	0.02	ND
Kg. Tengku Hussein	0.02	1.08	0.02	0.03
Gunung Lang	0.02	0.60	0.02	0.03
Taman Indah	0.04	0.78	0.01	0.03

Abbreviation: ND, not detected.

Arsenic (As)

Arsenic (As) is a type of metal that exists extensively in the earth crust. This metal is widely used as a powder, pesticide, food supplement and in the medical field. As can exist in water through smelting of rocks, minerals and ores. In addition, mining and industrial waste also contributes to the increase of as in water. This metal does not have any benefits to human health. Continuous exposure to as will increase the risk of cancer (WHO, 2011a). The guidelines for as in water are 0.05 mg/l (Class II) as established by the DOE and 0.01 mg/l as established by the MOH.

The average concentration of as in all of the lakes are presented in Figure 2. The trend of as concentrations are inconsistent based on the standards provided by the DOE, but they do not conform to the MOH standards for the five lakes. The As results from Lake Lahat shows a value ranged from 0.045 mg/l to 0.058 mg/l. Only samples taken in February and March 2016 were classified as Class II. The As concentrations in the lake water, particularly at station 3 and station 4, were relatively high, but the value decreased over time when compared to the first time

observation. According to Mahmud (2005), the presence of low concentrations of as in the lakes may be attributed to the process of weathering rocks and minerals, while high concentrations may be due to industrial activity and housing in the surrounding environment. From all observations, the average value of As in Lake Kg. Temiang was between 0.014 mg/l and 0.034 mg/l. The As concentration pattern was as follows: a decline between September 2015 and March 2016, a slight rise from March 2016 to June2016, and another decline until August 2016. This suggests that the as concentration pattern in the lake is inconsistent.

Different situations were detected in Lake Kg. Tengku Hussein, which had an average as concentration of between 0.013 mg/l and 0.029 mg/l. Referring to the pattern of as concentration changes in Figure 2, the value decreased from the beginning of the observation until August 2016. As was detected at Lake Gunung Lang at concentrations between 0.01 mg/l and 0.05 mg/l. For Lake Taman Indah, AS was detected at concentrations between 0.01 mg/l to 0.06 mg/l. The two lakes, Gunung Lang and Taman Indah, showed an inconsistent pattern throughout the observation. All observations show that the concentration of as is still in compliance with DOE standards for Lake Gunung Lang, whereas the concentration at Lake Taman Indah exceeded the level assigned by DOE for Class II with a value of 0.06 mg/l in April 2016.

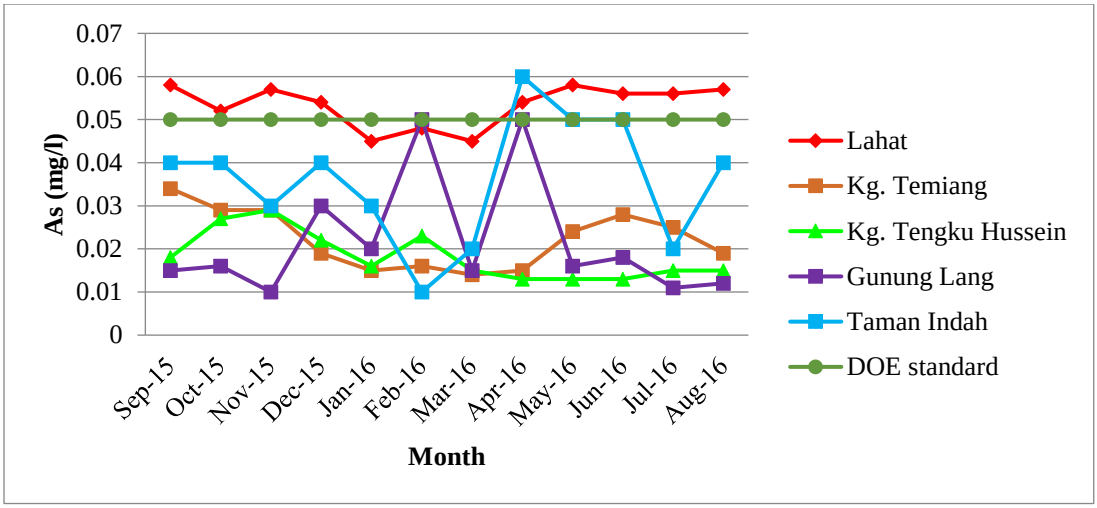

Figure 2. Changes in as concentrations during the sampling period in the study lakes.

Lead (Pb)

Pb is a toxic metal that has long been used by humans, especially in the domestic and household segments. Exposure to this metal, even at low rates, can cause various health-related problems such as problems in nervous system especially with babies, children under the age of 6 and pregnant ladies (WHO, 2011b). The main source of Pb is from paints and pipe materials (U. S. Environmental Protection Agency, 2014). WHO (2011b) also noted that this metal is used in the manufacture of batteries, alloys, ammunition and plastic stabilizers. Exposure to PB is associated with problems in the nervous system, especially for infants, children under six and pregnant women. The value of 0.05 mg/l of as in the water is considered to be Class II by the DOE as well as the MOH.

Average valuations of Pb are presented in Figure 3 for all observations. The findings show that not all observations are within the limits of the MOH standards. In short, for the DOE

standards, all of the observations showed that the water quality was contaminated with Pb and should be classified as Class III. This means that the quality of the lake water has exceeded the minimum level for body contact with water i.e. in Class II. On average, the presence of Pb in Lake Lahat was between 0.17 mg/l and 1.366 mg/l. Based on Figure 3, there was a significant increase in Pb contamination from October 2015 to March 2016. At Lake Kg. Temiang, the average Pb value was between 0.143 mg/l and 1.330 mg/l in June 2016. This lake was found to be contaminated with Pb, with a sudden increase in concentration from September 2015 to February 2016.

The situation at Lake Kg. Tengku Hussein was not much different; average Pb concentrations were between 0.164 mg/l and 1.335 mg/l. The lake was also in a contaminated condition with a drastic increase in Pb concentration between October and November 2015. The value was continuously high from November 2015 to August 2016. At Lake Gunung Lang, the average observation was between 0.31 mg/l and 0.94 mg/l. The presence of Pb in the lake declined between July and August 2016, but it still exceeded the level of Class II. The average concentration of Pb recorded in Lake Taman Indah was between 0.41 mg/l and 1.23 mg/l. The same situation was observed in which the value decreasing between February and August 2016. Continuous monitoring of all lakes is necessary to reduce the concentration of Pb in water so that water recreation activities can be developed.

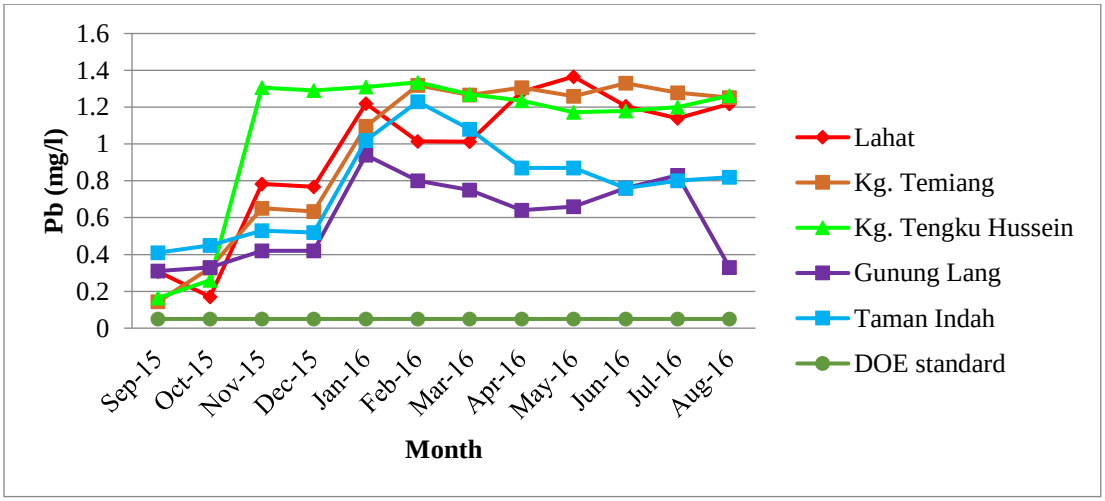

Figure 3. Changes in Pb concentrations during the sampling period in the study lakes.

Copper (Cu)

Copper (Cu) metal is derived from Cu ore, especially cuprit, azurite, chalkopirit and bornit. Typically, Cu ore will contain other metals, such as zinc, cadmium and molybdenum. These metals are used in the manufacture of electrical appliances, such as wires, pipes and water tanks. Humans need Cu in low quantities in foods, especially for the formation of blood haemoglobin (Ramlan, 1998). According to WHO (2004), exposure to Cu metal continuously at high doses of between 4 and 400 mg may cause kidney bleeding and damage. For this metal, the DOE sets the maximum value that should be in the water content of 0.02 mg/l (that is, Class II). MOH sets the value of this metal at 1.0 mg/l.

Average Cu observations over the study period are presented in Figure 4 for all the lakes. The Cu was not detected continuously in the water for all the lakes studied. In terms of MOH standards, all observations were in line with the guidance values. The average monthly observations of Cu at Lake Lahat were between 0.017 mg/l and 0.032 mg/l. Cu was not detected in July or August 2016. Periodic monitoring is needed to ensure that the concentration of Cu in the lake is under control. The same situation was observed at Lake Kg. Temiang, where the presence of Cu in the water was observed continuously. The average observation was between 0.016 mg/l to 0.027 mg/l. These parameters were not detected at any stations in September 2015, November 2015, June 2016, July 2016 or August 2016.

In Lake Kg. Tengku Hussein, the average Cu concentration was between 0.018 mg/l and 0.031 mg/l. These metals were not be detected in September2015, November 2015 or January 2016. Based on Figure 4, the concentrations of Cu decreased between June and August 2016. For Lake Gunung Lang and Lake Taman Indah, all of the observations showed that the concentrations of Cu met the standards set by the DOE. These analyses demonstrated that the water was safe for water recreation. Both lakes recorded an average Cu value of 0.01 mg/l to 0.02 mg/l.

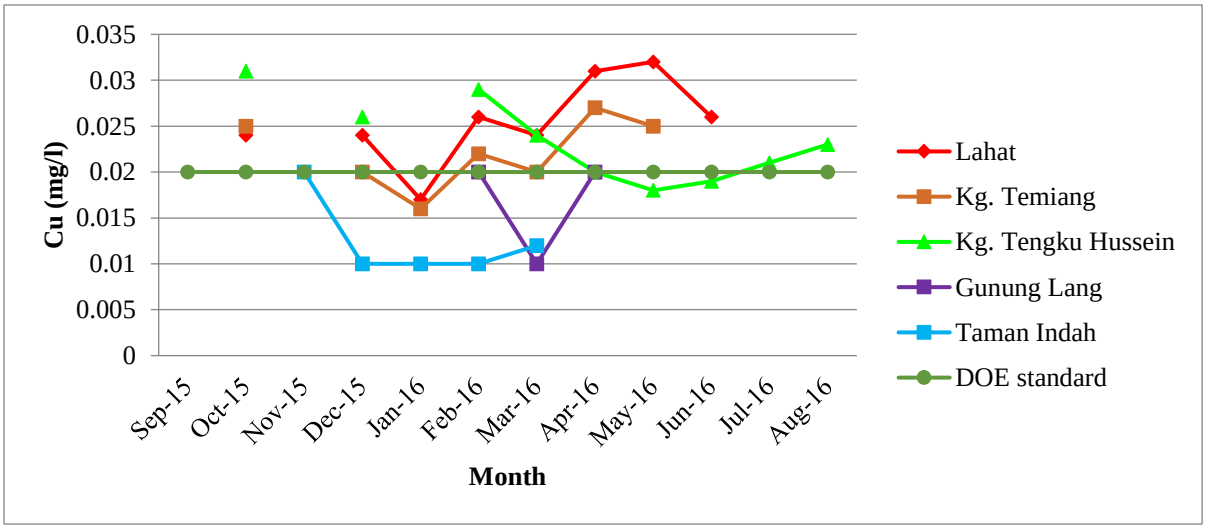

Figure 4. Changes in Cu concentrations during the sampling period in each of the study lakes.

Zinc (Zn)

Zn is soft, easy to dissolve and react easily with inorganic materials. This metal is widely used in the manufacture of alloys, steel and iron (Ramlan, 1998). Humans require Zn as part of daily nutrition at a dose of 0.3 mg/kg; the maximum amount that can be taken at one time is 1.0 mg/kg. However, the excessive intake of Zn will cause side effects. Among the recognisable effects are vomiting, diarrhoea, poisoning and spasms (WHO, 2003). Based on the standard water quality of the DOE, the maximum value set for the presence of Zn in water is 5 mg/l (Class II). The MOH set a value of 3 mg/l for the presence of this metal in water.

The analyses of Zn are presented in Figure 5 for all observations. Overall, Zn was not detected during any of the observation months at Lake Lahat or Lake Kg. Temiang. This demonstrates that that Zn pollution does not exist in the lakes studied. For Lake Kg. Tengku Hussein, this metal was only be detected in November 2015 with a concentration of 0.03 mg/l at

station 2. At Lake Gunung Lang, the concentration of Zn was found to be between 0.02 mg/l and 0.05 mg/l. For Lake Taman Indah, the detected value was between 0.02 mg/l and 0.04 mg/l. Despite the presence of Zn in Lake Kg. Tengku Hussein, Gunung Lang and Taman Indah, the concentration was controlled and did not exceed Class II. The detected concentrations also met the standards set by the MOH.

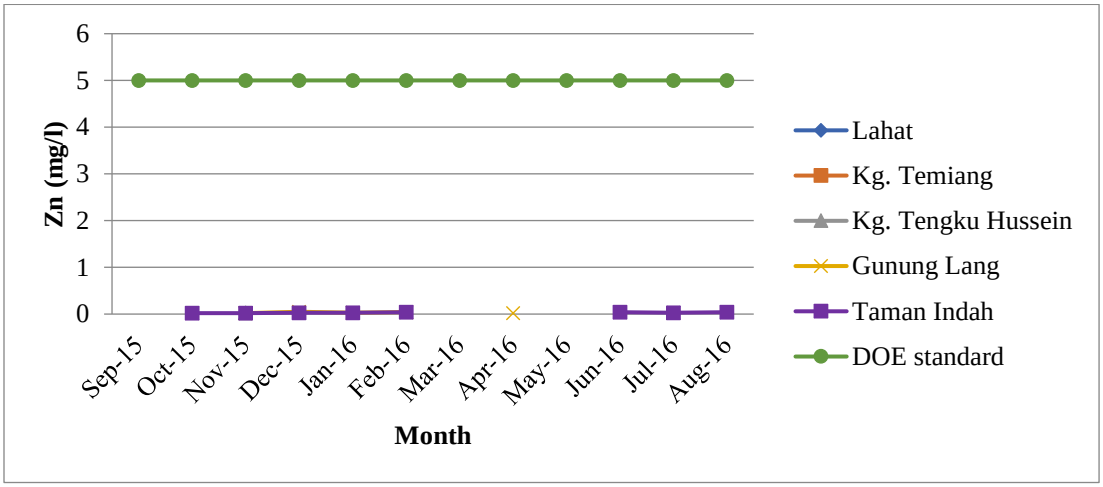

Figure 5. Changes in Zn concentrations during the sampling period in the study lakes.

Conclusion

In summary, the heavy-metals analyses have demonstrated that water quality varies based on the months of observation. Based on the results of this study, all of the lakes were contaminated with Pb, and the valuation did not meet the standards of the DOE or the MOH. For As, although the water quality did not meet the MOH standards, it was still appropriate to use for recreational purposes based on the DOE standards. Other parameters also showed readings that were not under control during the sampling period. The average results indicated that all lakes were suitable for redeemable use for water recreation activities. Periodic monitoring, as carried out by Ipoh City Council to Lake Gunung Lang, is very important to ensure that the quality of water continues to be under the limits. This study can be used as an initial guide for maintaining the water quality so that it does not continue to deteriorate due to increasing concentrations of heavy metals. The ongoing water quality control by the Ipoh City Council is able to transform the idle mining area into a valuable asset to the community and to the nation.

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Corresponding Author

Dr. Mohmadisa Hashim, PhD
Department of Geography & Environment,
Faculty of Human Sciences,
Universiti Pendidikan Sultan Idris,

35900 Tanjong Malim, Perak, Malaysia.
Email: mohmadisa@fsk.upsi.edu.my

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