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Water Quality Assessment of Former Tin Mining Lakes for Recreational Purposes in Ipoh City, Perak, Malaysia

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Abstract A study of the water quality of the former tin mining lakes in Ipoh City was carried out to determine the Water Quality Index (WQI) and classification based on the Malaysia National Water Quality Standards, in order to determine its suitability to be developed as a water recreation area. Five former mining lakes were chosen: Gunung Lang, Taman Indah, Kg. Temiang, Lahat and Kg. Engku Husin. The parameters measured were pH, dissolved oxygen, suspended solids, biochemical oxygen demand, chemical oxygen demand and ammonical nitrogen (NH3N), while the heavy metals measured were lead (Pb), copper (Cu), zinc (Zn) and arsenic (As). The analytical study shows that four former mining lakes in this research are suitable to be developed for water recreation purposes as they are classified under class II with a WQI greater than 81, which holds a clean status. Only one lake, Kg. Engku Husin, is categorised as class III, which requires an intensive treatment before it can be used for recreational purposes. Meanwhile, heavy metals such as Zn, As and Cu were at the standard level except for Pb, which exceeded the set guidelines. The local authorities and project developers should take appropriate measures to ensure that this former mining lake is well maintained and managed so that it is preserved and suitable to be developed as a recreational area.

Keywords: Water Quality, Tin Mining, Ipoh City

Abstrak *Tujuan dari kajian kualitas air di danau bekas galian tambang timah di Kota Ipoh adalah menentukan Indeks Kualitas Air (IKA) berdasarkan pada Standar Nasioanal Kualitas Air Malaysia. Indeks kualitas ari tersebut digunakan untuk menilai kesuaian peraian danau untuk dikembangkan menjadi obyek wisata air. Danau yang dikaji dalam penelitian ini meliputi Gunung Lang, Taman Indah, Kg. Temiang, Lahat dan Kg. Engku Husin. Paramater kualitas air yang dianalisis meliputi pH, oksigen terlarut, padatan terlarut, BOD, COD, NH3N, Pb, Cu, Zn, dan As. Hasil penelitian menujukkan bahwa emat telaga di Kota Ipoh termasuk dalam kategori Kelas II dengan nilai IKA lebih besar dari 81 dengan status sebagai air bersih. Hanya danau Kg. Engku Husin yang termasuk dalam kategori Kelas III, sehingga tidak memenuhi persyaratan untuk untuk pengembangan wisata air. Unsur pencemar yang melampau ambang batas baku mutu di danau Kg. Engku Husin adalah Pb, sementara Zn, As, dan Cu masih memenuhi baku mutu air yang dipersaratkan. Danau Kg. Engku Husin memerlukan pengolahan air yang sangat intensif sebelum danau tersebut dapat digunakan untuk pengembangan wisata air. Pemerintah daerah dan pengembang wisata di kelima danau bekas tambang tersebut harus melakukan upaya agar danau bekas tambang di Kota Ipoh dapat dipelihara dan dikelola untuk pengembangan kawasan wisata.*

Kata kunci: *Kualitas Air, Penambangan Timah, Kota Ipoh*

1. Introduction

The existence of former mining lakes in Malaysia presents a significant impact from abandoned mining activities, particularly tin mining. The pressure of development and the increase in the population resulted in increased demand for former mining lakes to be converted to a more productive land use, such as areas of recreation, agriculture and animal husbandry [Town & Country Planning Department of Peninsular Malaysia, 2010]. However, not all former tin mining lakes are suitable to be developed, especially when it comes to mine water reclamation itself for socio-economic activities. Furthermore, heavy metal content and mine water quality need to be considered before the mine water is used as an alternative source of drinking water [M. Widyastuti and Eko Haryono, 2016; Ku Orji et al., 2013; Ashraf et al., 2011 & 2012; Yusof et al., 2001].

Since former mining lakes are the most dominant lake types in Ipoh City area, the transformation of the former mining land into recreational land use is significant. Not all kinds of development are suitable for mining land reclamation, especially that involving lake water reclamation for recreational activities. Chemicals consisting of inorganic heavy metals are commonly found in a variety of chemical and physical forms [Spellman, 2010; Mohmadisa et al., 2012; Nasir et al., 2014]. Heavy metals pollution is an issue that should be taken seriously. Muhamad Samudi et al. [2008] explain that the impact of mining activities will result in increased concentrations of heavy metals in the ecosystem. Meanwhile, Azilah and Raslinda [2006] state that the development of a recreational lake is important to create a healthy, safe, comfortable, interesting and

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entertaining life.

Therefore, the suitability of reclaiming the former mining lakes for water recreational activities in Ipoh should be reviewed. The purpose of this study is to examine the extent to which previous mining activities have increased the level of heavy metals in the water, which can eventually affects not only the ecosystem of the lake but also the lives of the local people. This study of the former mines' water quality is important in proving the suitability of reclaiming the former mining lakes for recreational purposes. Hence, this study will provide guidelines for local authorities, especially the Ipoh City Council in planning appropriate development activities to be established on the former tin mining land.

2. The Methods

This study on the changes in land use and water quality of the former tin mining lakes was conducted around Ipoh City, Perak. Ipoh City is the state capital of Perak, which is located in the district of Kinta (Figure 1). With an area of 64,257 hectares, the administrative area of Ipoh City Council can be divided into three districts, including: Mukim Ulu Kinta (62 812.37 hectares); Mukim Sungai Raia (1 363 hectares) and Mukim Sungai Terap (81.63 hectares) [Town & Country Planning Department of Peninsular Malaysia, 2010]. In general, the current land use is: forested area, namely Hutan Simpan Kledang and Bukit Kinta (48.1%); vacant land that includes former mining area, abandoned land and committed development sites (15.63%) and built-up areas including residential, industrial, commercial and institutional land (14.39%).

There is plenty of vacant land being developed, particularly at former tin mining sites, in the study area. Former mining lands are also reclaimed as committed development sites among other purposes [Nasir et al., 2016; Husna et al., 2012]. One of them is for recreational purposes, in which the former mining lake is maintained for fishing, leisure and other recreational activities area. For the purpose of recreational activities, this study has identified five former mining lakes to be assessed for water quality status (Table 1). These lakes were justifiably chosen as the location for this study as they are currently being, or plan to be, developed as recreational areas [Planning Department of Ipoh City, 2015].

The water quality sampling of the former tin mining lakes was carried out twice: on 3rd to 4th November 2015 and 3rd to 4th January 2016. A total of three water samples were taken at each former mining lake. The location coordinates of the sampling stations were determined using the Meridian Global Positioning System (GPS). In general, physical, chemical and biological parameters of the water quality were measured. Six key parameters were chosen for the assessment of Water Quality Index (WQI) as specified by the Department of Environment (DOE): dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonical nitrogen (NH3N), suspended solids (SS) and pH. In addition, other parameters measured included heavy metals such as lead (Pb), copper (Cu), arsenic (As) and zinc (Zn). The two water quality parameters measured on the site or in-situ were pH and DO (mg/L) using the YSI Multi Parameter Probe. Meanwhile, the parameters for the analysis of water quality samples in the laboratory were SS, BOD, COD, NH3N and heavy metals Pb, Cu, As and Zn.

The laboratory analysis was performed in the Physical Geography Laboratory, Sultan Idris Education University. For each of the former tin mining lake, the surface water samples to determine the WQI were collected in three polyethylene bottles (1000 mL) and stored in a dark, cold place (4°C). In the laboratory, the samples were stored in the refrigerator (4°C) before being analysed to determine the level of SS, BOD, COD, NH3N and heavy metals Pb, Cu, As and Zn. For the water quality parameters such as pH and DO, the data were recorded at each sampling station using the YSI Multi Parameter Probe. The BOD value was determined based on the DO before and after the samples were incubated in the incubator at 20°C, while the COD value was calculated based on the open reflux method. The value of SS was calculated based on the difference in weight of the 0.45um pore size membrane paper before and after the sample being filtered through it. The water samples were analysed using Inductively

Table 1. The Locations of Former Mining Lake Area

Location	Latitude	Longitude	Characteristics of Sampling
Gunung Lang	4.629081	101.093294	Former mine, recreational area
Taman Indah	4.656417	101.162238	Former mine, flood control reservoir
Kg. Temiang	4.579084	101.071224	Former mine, fishing pond
Lahat	4.543373	101.038331	Former mining area close to residential area
Kg. Engku Husin	4.615855	101.063094	Former mining area close to residential area

Table 2. Malaysia Water Quality Index

WQI	Clean	Moderately Polluted	Polluted
	81 - 100	60 - 80	0 - 59

Table 3. The Locations of Former Mining Lake Area

WQI	Recreation
70 – 100	Suitable for all types of water sports
50 – 70	Increasingly polluted, still suitable, bacterial count required
38 – 50	Water sports with body contact is doubted
32 – 38	Sports activities without body contact
20 – 28	Pollution is becoming more obvious
0 – 20	Unsuitable

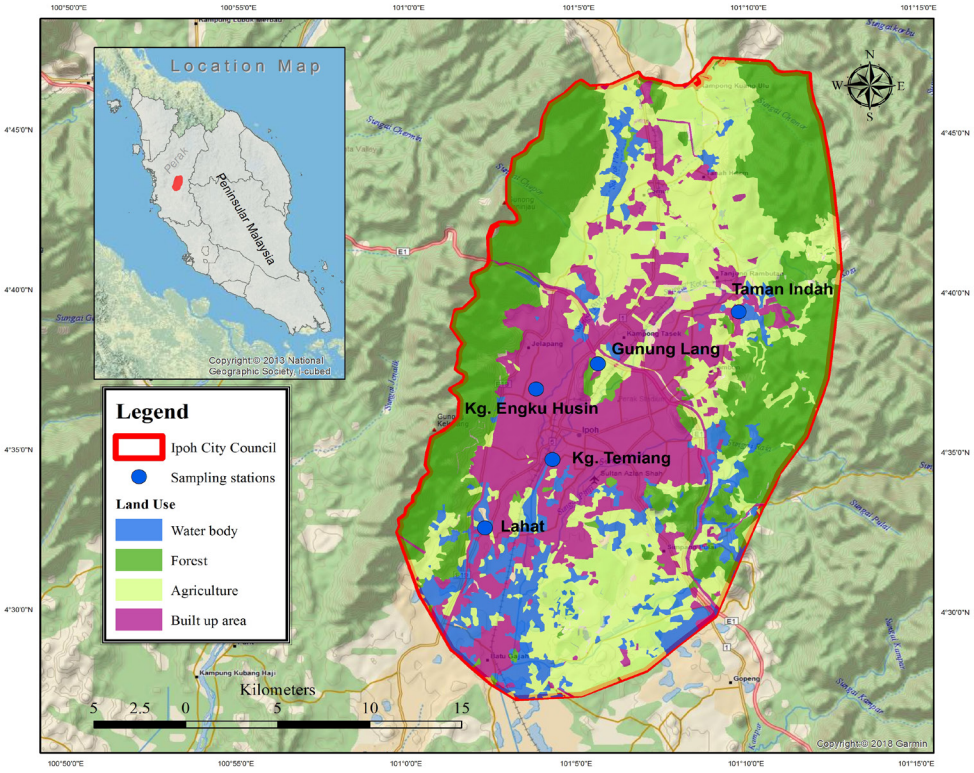

Figure 1. Land Use Map of Ipoh City
Source: Town and Country Planning Department of Peninsular Malaysia, 2010

Coupled Plasma Mass Spectrometry (ICP-MS) to determine the concentration of heavy metals. This study analysed the status of the water quality based on the Malaysian standards as outlined by the Malaysia WQI and WQI for recreational activities as defined by DOE (Table 2 and Table 3) [DOE, 2008].

3. Results and Discussion

The values of WQI for all five former tin mining lakes were between 74 and 91 in the month of November 2015 and between 74 and 93 in January 2016. The WQI values in November 2015 show that the water quality in the study area came under class II and III (Table 4). The locations under class III water quality were Taman Indah and Kg. Engku Husin, while Gunung Lang, Kg. Temiang and Lahat came under class II. In January 2016, the values of WQI indicate that the water quality of all former tin mining lakes showed no changes, except in Taman Indah, which changed from class III to class II (Table 5). The WQI values of the study stations categorised under class III will require intensive treatment before they can be used for water recreational purposes that involve water-human contact.

Meanwhile, the water quality of the former mining lakes was also analysed based on their suitability for recreational activities as recommended by the DOE

Table 4. The overall WQI values for the month of November 2015 (in percent)

Location/ Values	DO	BOD	COD	NH3N	SS	pH	WQI	Class	Status
Gunung Lang	83	97	92	96	88	92	91	II	Clean
Taman Indah	7	89	87	59	89	99	67	III	Moderately Polluted
Kg. Temiang	59	95	84	98	94	96	86	II	Clean
Lahat	73	94	98	100	95	96	91	II	Clean
Kg. Engku Husin	6	89	91	100	91	99	74	III	Moderately Polluted

Table 5. The overall WQI values for the month of January 2016 (in percent)

Location/ Values	DO	BOD	COD	NH3N	SS	pH	WQI	Class	Status
Gunung Lang	93	91	80	98	97	89	92	II	Clean
Taman Indah	95	91	84	97	97	92	93	II	Clean
Kg. Temiang	60	96	82	80	97	94	83	II	Clean
Lahat	94	95	87	89	97	92	93	II	Clean
Kg. Engku Husin	19	80	80	94	97	98	74	III	Moderately Polluted

Table 6. Suitable recreations based on WQI of the study area for the month of November 2015

Location	WQI	Notes
Gunung Lang	91	Suitable for all types of water sports
Taman Indah	67	Increasingly polluted, still appropriate, bacterial count required
Kg. Temiang	86	Suitable for all types of water sports
Lahat	91	Suitable for all types of water sports
Kg. Engku Husin	74	Suitable for all types of water sports

[2008]. Based on Table 6, in November 2015 results from all of the observation sites, except Taman Indah, indicate that the WQI status is suitable for all kinds of water sports. Again, in January 2016 the WQI values recorded for all stations indicate that the lakes are suitable for all kinds of water sports (Table 7).

Measurement of Physico-Chemical Parameters

The next analysis was based on each parameter observed on the site and in the laboratory analysis. Comparisons were made between the two-time observations: November 2015 and January 2016. It was found that the DO levels in all five former tin mining lakes in November 2015 ranged from 1.21 to 5.60 mg/L and 2.20 to 6.58 mg/L in January 2016 (Figure 2). The highest DO value in November 2015 was at Gunung Lang (5.60 mg/L) and in January 2016 was at Taman Indah (6.58 mg/L). The lowest DO value readings were at Taman Indah in November 2015 and at Kampung Engku Husin in January 2016, with readings 1.21 mg/L and 2.20 mg/L, respectively. As for the DO parameter in November 2015, all stations were classified as class III (3 to 5 mg/L) or below, except for the former mining lake in Gunung Lang, which was classified as class II (5 to 7 mg/L).

The difference between the readings made in November 2015 and January 2016 indicate that there was a significant increase in the DO value at Taman Indah compared to other locations. This is because in November an infrastructural construction process for recreational purposes took place around the former mining lake and the exposed soil around the mine. These sediments were transported into the mine during heavy rain and caused the DO readings to be low during that month. However, in January 2016 the construction of recreational infrastructure in this had stopped and this caused the DO readings in the area to increase again.

The BOD measurement is generally a specific measurement used in determining the amount of oxygen needed for organic material to decompose [Ashraf et al., 2010; Sukiman, 1989]. The aim of measuring BOD is usually associated with the measuring of organic carbon content. The BOD values for all five of the former mining lakes ranged from 0.73 to 2.79 mg/L in November 2015 and 0.98 to 4.9

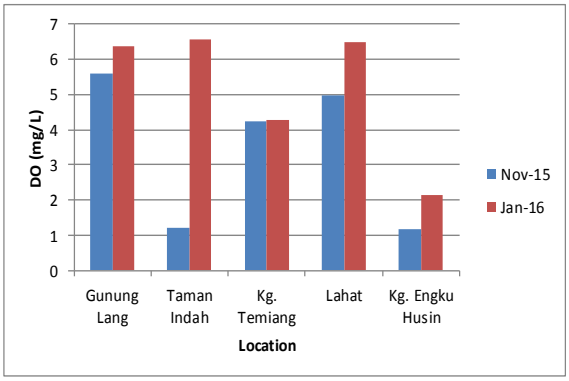

Figure 2. The average value of DO (mg/L)

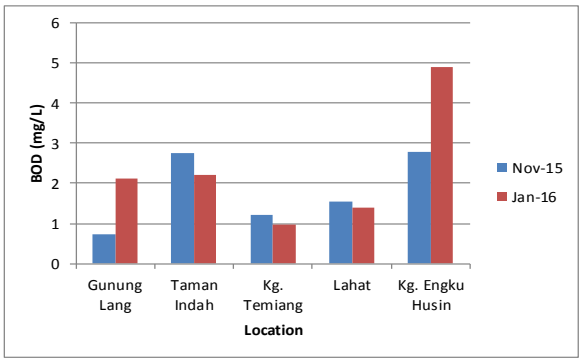

Figure 3. The average value of BOD (mg/L)

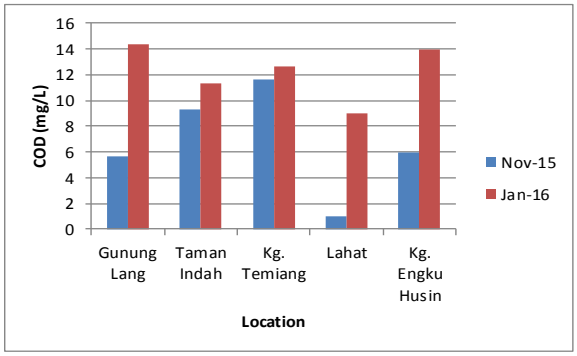

Figure 4. The average value of COD (mg/L)

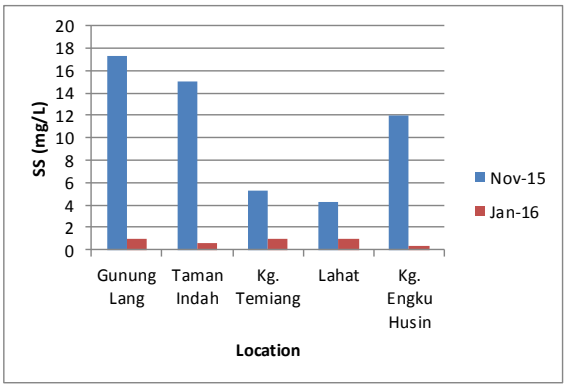

Figure 5. The average value of SS (mg/L)

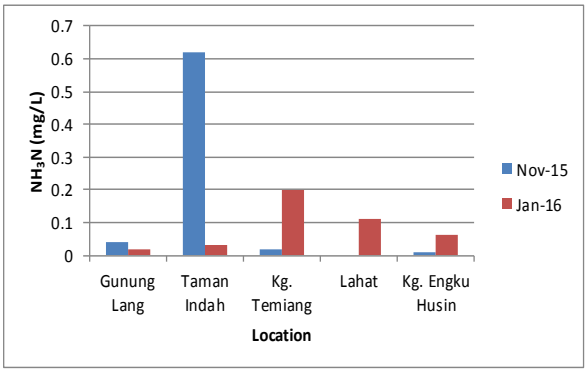

Figure 6. The average value of NH3N (mg/L)

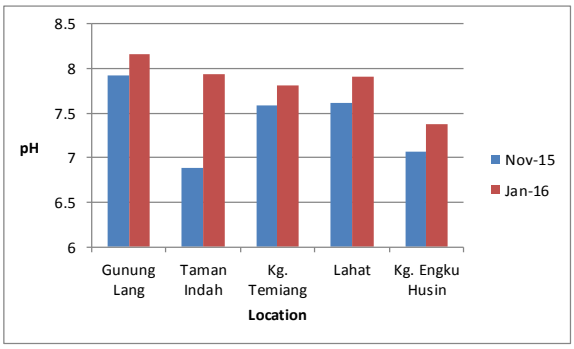

Figure 7. The average value of pH

Photo 1. Restaurants that are located near lake Kg. Temiang which channel their domestic water waste directly into the lake

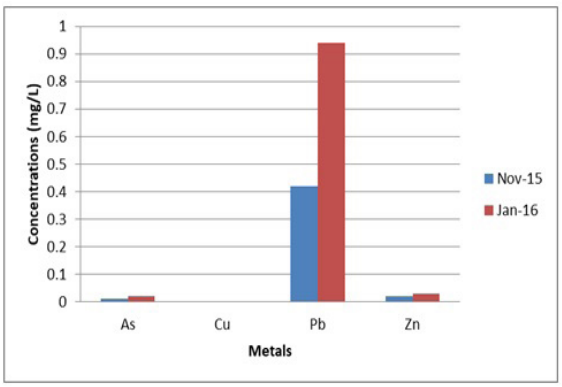

Figure 8. The average values of Pb, Zn, As and Cu (mg/L) in the Gunung Lang former mine

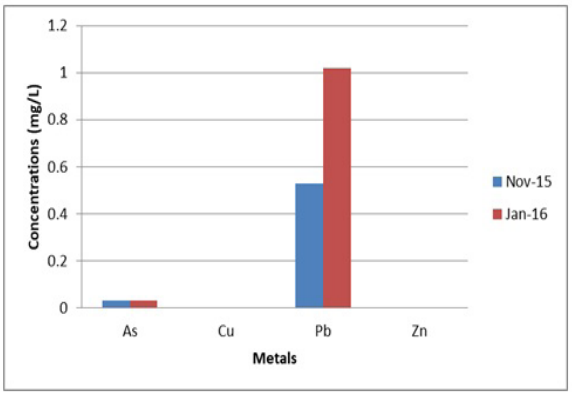

Figure 9. The average values of Pb, As, Zn and Cu (mg/L) in Taman Indah former mine

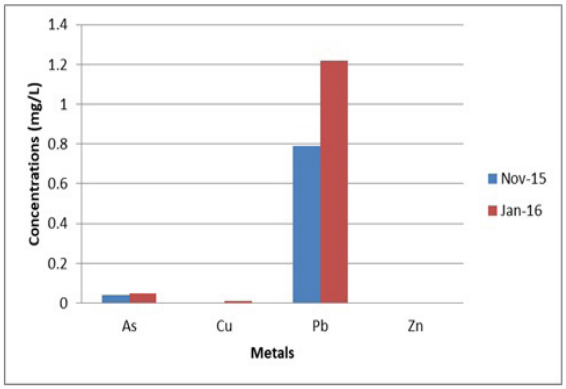

Figure 11. The average values of Pb, As, Cu and Zn (mg/L) in Lahat former mine

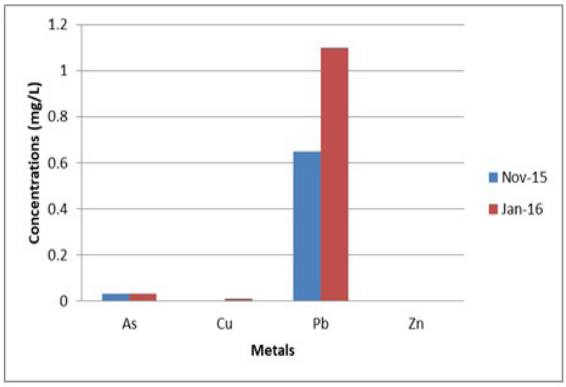

Figure 10. The average values of Pb, As, Zn and Cu (mg/L) in Kg.Temiang former mine

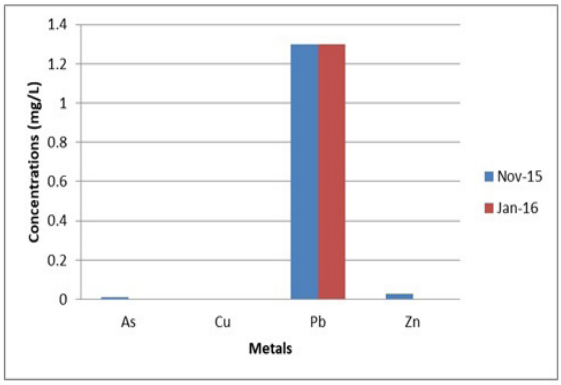

Figure 12. The average values of Pb, Zn, As and Cu (mg/L) in Kg. Engku Husin former mine

Table 8. Heavy metal concentrations in November 2015

Metals	NWQS (Class II) mg/L	Gunung Lang	Taman Indah	Kg. Temiang	Lahat	Kg. Engku Hussin
As	0.05	0.01	0.03	0.03	0.04	0.01
Cu	0.02	0.00	0.00	0.0	0.00	0.00
Pb	0.05	0.42	0.53	0.65	0.79	1.30
Zn	5	0.02	0.00	0.00	0.00	0.03

Table 9. Heavy metal concentrations in January 2016

Metals	NWQS (Class II) mg/L	Gunung Lang	Taman Indah	Kg. Temiang	Lahat	Kg. Engku Hussin
As	0.05	0.02	0.03	0.03	0.05	0.00
Cu	0.02	0.00	0.00	0.01	0.01	0.00
Pb	0.05	0.94	1.02	1.10	1.22	1.30
Zn	5	0.03	0.00	0.00	0.00	0.00

mg/L in January 2016 (Figure 3). Kg. Engku Husin recorded the highest BOD reading in November 2015 and January 2016 with readings of 2.79 mg/L and 4.90 mg/L, respectively. Samples with the lowest BOD for the month of November 2015 were from Gunung Lang and from Kampung Temiang in January 2016, with recorded readings as low as 0.73 mg/L and 0.98 mg/L, respectively. As for the BOD parameters in November 2015, all stations were classified as class I (1 to 3 mg/L). All stations remained in this class in January 2016, except for the former mining lake in Kg. Engku Husin, which was classified as class II (3 to 6 mg/L).

The COD is used to measure how bad the pollution is. COD is the amount of oxygen required to oxidise the

tested compounds (Ku Orji et al., 2013; Mohd Harun, 2012). The COD values for these five former mining lakes in November 2015 ranged from 1.00 to 11.67 mg/L and from 9.00 to 14.33 mg/L in January 2016 (Figure 4). The COD parameters in November 2015 and January 2016 at all stations were classified as class I (10 to 25 mg/L). This high COD value is due to the large presence of inorganic substances (Mazlin et al., 2001). One of the sources of inorganic material is from metal residues [Hafemeister, 2007].

The SS in water is used to determine the amount of solid material suspended in water. High in SS causes turbidity and results in sedimentation problems [Ahmad et al., 2014; Zaini et al., 2011a; 2011b]. Water with a high level of SS is not suitable for domestic use. The SS values for the five former mining lakes in November 2015 ranged from 4.33 to 17.33 mg/L and from 0.40 to 1.00 mg/L in January 2016 (Figure 5). The highest SS value in November 2015, recorded in the former mining lake area of Gunung Lang, was as high as 17.33 mg/L. In January 2016 the highest reading of 1 mg/L was recorded at the former mining lake area in Kg Temiang and Lahat.

The data collected show that the readings in November 2015 and January 2016 were significantly different based on the highest readings of the samples that were taken twice. This is because in November 2015 the study area received a high quantity of rainfall compared to January 2016. The rain transported suspended sediments into the former mining lake area, which resulted in the increased SS readings from the lake. The parameters of SS in November 2015 and January 2016 however were classified as class I for all stations (25 mg/L).

NH3N in water is an indication that pollution is caused by human or animal sewage. NH3N is highly toxic and harmful to aquatic life. NH3N concentration values for the five former mining lakes in November 2015 ranged from 0 to 0.62mg/L and from 0.10 to 0.20mg/L in January 2016 (Figure 6). The highest NH3N value in November 2015 was recorded at the former mining lake in Taman Indah (0.62 mg/L), while the highest reading in January 2016 was recorded at the former mining lake in Kg. Temiang (0.20 mg/L). As for the NH3N parameter in November 2015, all stations were classified as class I (1.0 mg/L), except for the former mining lake in Taman Indah, which came under class II (3 mg/L). In January 2016 all stations were classified as class I (1.0 mg/L), except for the former mining lake in Kg. Temiang, which came under class II (3 mg/L). This high concentration of NH3N is likely due to the disposal of general or domestic waste into the former mining lake by the local residents. Photo 1 shows the restaurants that directly channel their domestic water waste into lake Kg. Temiang. According to Nasir et al. [2014], the concentration of NH3N was caused by the release of fertilisers, animal waste and domestic sewage into the water through surface runoff during rain events.

The pH values of all five former mining lakes in November 2015 ranged from 6.89 to 7.92, while in January 2016 the range was from 7.40 to 8.16. on both sampling dates all stations were classified as class I (6.6 to 8.5). The pH values were lower in November 2015 because of the Northeast Monsoon season rain that brought polluted and acidic materials from the soil surface into the aquatic environment [Nasir et al., 2014].

Determination of Heavy Metal Concentrations

Among the sources of pollution resulting from the former tin mining lakes are heavy metals, such as mercury (Hg), arsenic (As), cadmium (Cd), zinc (Zn), copper (Cu) and lead (Pb) [Kah et al., 2016; Ku Orji et al., 2013; Ashraf et al., 2012; Zulhadi, 2006]. In this study, the analysis of heavy metals were limited to Pb, Cu, As and Zn in the water around the former mining lake area. The water sampling was carried out at the sites in November 2015 and January 2016 (Table 8 and Table 9).

In November 2015, at the former mining lake at Gunung Lang the concentrations of Pb, Cu, As and Zn were 0.42 mg/L, 0.0 mg/L, 0.01 mg/L and 0.02 mg/L, respectively. In January 2016 the readings recorded for Pb, Cu, As and Zn were 0.94 mg/L, 0.0 mg/L, 0.02 mg/L and 0.03 mg/L, respectively (Figure 8). In general, the metal concentrations in the water at Gunung Lang former mine decreased in the order of Pb > Zn > As > Cu. The concentration of heavy metals measured in mg/L is benchmarked against the Malaysian National Water Quality Standards. The same measurement is adopted by the Department of Environment of Malaysia, the authority that regularly performs water quality assessment.

At the former mining lake in Taman Indah, the readings in November 2015 for Pb, Cu, As and Zn metal concentration were 0.53 mg/L, 0.0 mg/L, 0.03 mg/L and 0.00 mg/L, respectively. In January 2016 the readings of Pb, Cu, As and Zn were 1.02 mg/L, 0.0 mg/L, 0.03 mg/L and 0.00 mg/L, respectively (Figure 9). In general, the metal concentrations in the water of Taman Indah former decreased in order of Pb > As > Zn > Cu.

At the former mining lake in Kg. Temiang, the readings in November 2015 for Pb metal concentration was 0.65 mg/L, Cu (0.0 mg/L), As (0.03 mg/L) and Zn (0.00 mg/L), while in January 2016 the reading of Pb was recorded as 1.10 mg/L, Cu (0.01 mg/L), As (0.03 mg/L) and Zn (0.00 mg/L) (Figure 10). In general, the metal concentrations in the water of Kg. Temiang former mine is in the descending order of Pb > As > Zn > Cu.

As for the former mining lake in Lahat, the readings in November 2015 for Pb, Cu, As and Zn metal concentrations were 0.79 mg/L, 0.0 mg/L, 0.04 mg/L and 0.00 mg/L. In January 2016 the recorded values of Pb, Cu, As and Zn were 1.22 mg/L, 0.01 mg/L, 0.05 mg/L and 0.00 mg/L, respectively (Figure 11). In general, the

metal concentrations in the water of Lahat former mine decreased in the order of Pb > As > Cu > Zn.

At the former mining lake in Kg. Engku Husin, the readings in November 2015 for Pb, Cu, As and Zn metal concentrations were 1.30 mg/L, 0.0 mg/L, 0.01 mg/L and 0.03 mg/L, respectively. In January 2016 the recorded values of Pb, Cu, As and Zn were 1.30 mg/L, 0.0 mg/L, 0.00 mg/L and 0.00 mg/L (Figure 12). In general, the metal concentrations in the water of Kg. Engku Husin former mine decreased in the order of Pb > Zn > As > Cu.

Lead is a heavy metal element, derived from the nature, which is abundant in the earth's crust. It can also be found in water, soil and plants. Among these three sources, it is most readily found in soil and water. The presence of Pb heavy metal does not actually benefit the body, even in low concentrations. Instead, it will remove or replace other metals from specific cell binding sites, which ultimately leads to various detrimental effects to human health as it is easily absorbed by a growing body. Its accumulation in a developing body will disrupt the natural growth of cells in the body [Husna et al., 2012; Razak, 1996]. In general, heavy metal Pb is traced in all the lakes under the study. Its amount is higher compared to other metals such as Zn, As and Cu. The high value of Pb is attributable to the fact that these lakes were previously tin mines. However, this value is still considered low and still suitable and safe for water-based recreational activities.

4. Conclusion

Former tin mining areas not only act as a natural water catchment area to control the floods, but at the same time can be developed as a recreational area for the local population. This study found that all of the five studied former mining lakes are suitable for water-based recreational purposes. Based on the WQI all the former mining lakes have an appropriate WQI to develop the area into a water sports recreational area. The difference in readings between November 2015 and January 2016 were due to increased precipitation in the rainy season. All of the lakes have low concentrations of heavy metals especially Zn, As and Cu, but Pb was found to be at a high concentration due to the nature of the former mining lakes.

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