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Research paper

Assessment of Iron Ore Ex-Mining Lake: Seasonal Influence on Water Quality of Tasik Puteri, Bukit Besi, Malaysia

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Abstract

Tasik Puteri, Bukit Besi has been chosen to be monitored its water quality seasonally since it is known as the main water source for iron ore washing process a decade ago. In this study, water samples from 14 sampling station were analyzed for dissolved oxygen, pH, electrical conductivity (EC) and temperature in three different seasons, which covered the normal season (August 2016), wet season (November 2017) and dry season (Jan 2018). This study revealed that the lake is acidic with pH range from 2.96 – 4.32 in normal season, 2.80 – 4.40 in the wet season and 2.85 – 3.88 in dry season clearly fall in Class V of the Interim National Water Quality Standard (INWQS), which is highly polluted water where none of the uses of the other classes can be applied to the water. The mean temperature for the three months was within the normal range which is Class I, electrical conductivity are categorized under class I while dissolved oxygen in Class I for normal season, Class IIA/IIB for wet season and Class I for dry season. Statistical analysis of one way ANOVA test indicates that all measured parameters are shown significant difference by the seasonal changes. In summary, the water quality of Tasik Puteri, Bukit Besi should be extensively monitored since deterioration of water quality was clearly observed in terms of pH.

Keywords: *Water_sustainability; toxicity; pollution; adsorption;physicochemical*

1. Introduction

Water is essential for all living things to reproduce and grow. Water resources are sources of water that are potentially useful for industrial, agricultural, recreational, environmental activities and household. Wide spectrum of natural and human influences played an important role for the quality of water. The quantity and quanlity of water influenced by geological, hydrological and climatic [1]. Fresh water will be a limited resources in the future making water quality assessment is vital and become global concern [2]. Potential human health risk, low product quality and low profit are the results of bad water quality which contain contaminants that can impair growth, reproduction, impair development or even cause mortality to the cultured species [3]–[5]. The ground and surface water resources should be regular monitored and policies and ways should be adopted to preserve them from become imperious since all diseases (80%) contracted by human beings are from water sources which is revealed by the World Health Organization (WHO) [6]. The assessment of water quality of lakes can be done in several ways such as the use of Water Quality Index (WQI) which is well known tool, the use of local standards such as the use of ecological models for water quality prediction and the Interim National Water Quality Standards (INWQS) Malaysia[7, 8].

Mine tailing or processing waste is the waste solids or slurries that remain after the treatment of minerals by separation processes (e.g. rinding, crushing, flotation, size-sorting and other physicochemical techniques) to separate the valuable minerals from the less valuable rock, are a major source of contaminant, especially heavy metals in water [9]. Huge quantities of waste rocks and waste materials generated from mining are normally dumped on the surrounding area, land and stream that disrupts ecosystem, destroys microbial communities and scars the landscape [10]. Geochemical and biological reactivity of the aquatic system usually are determined by distribution of heavy metal pollutants within the water body. When heavy metal contents exceed their permissible limit, there are highly toxic [11. Low pH enhances heavy metal suspension in surface water and a sign for acid mine drainage pollution which is a characteristic feature of both abandoned and live mines [12].

Tasik Puteri is one of the man-made lake resulted from mining activities in an abandoned mine that took place last four decades. The lake started from a stream, and a dam was built from Sungai Dalam stream for the purpose of water supply for iron ore washing process [13]. Amongst the types of rock mined at Bukit Besi were iron ore with massive sulphide, which consists of pyrite (FeS_2), pyrrhtotite (Fe1-xS), calcopyrite ($CuFeS_2$), bernite (Cu_5FeS_4), hornfel (SiO_2) and dolerite with a smaller quantity of hematite (Fe_2O_3), limonite ($2Fe_2O_3.3H_2O$) and magnetite (Fe_3O_4) [14]. Soil and water analysis carried out have shown that the surface water and soil at an ex-iron mine near Bukit Besi in Dungun, Terengganu are known to be heavily contaminated [15], mainly due to acid mine water generated from sulfidic waste material [16], with the surface sediments of ex-mining catchments are contaminated with highly concentrated heavy metals [17]. Tasik Puteri, Bukit Besi is opened for public access, regardless of abundant and above the permissible limit of INWQS of the dissolved and undissolved heavy metals in the lake, even though the mining activities have stopped for nearly a decade ago. With regards to the previous study and reopening of the mining area since 2017, a seasonal analysis has to be conducted to see the trend of water quality. So, the aim of this study is to determine the changes of Tasik Puteri water quality mainly on in situ analysis within three different years in association to the seasonal variation.

2. Material and Methods

2.1. Sampling Location

Tasik Puteri is located at 4°44'00.2"N 103°11'31.0"E in Dungun district in between of Universiti Teknologi MARA, Bukit Besi Campus and Kampung Besol, Bukit Besi, Terengganu, Malaysia. The width of the lake from stream inlet to stream outlet is 1.4 km and the length of 1.9 km.

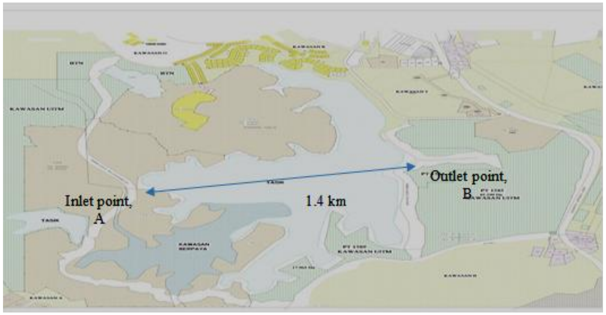

Fig. 1: The map of the lake showing the location of Tasik Puteri, Bukit Besi, Dungun, Terengganu, Malaysia.

A 14 sampling points was chosen from inlet to outlet water stream using an equal width increment method, spread through the 1.4 km width of the lake. Global positioning system was used to determine the actual coordinates of every single point form the water stream inlet to the water stream outlet due to large study area. A depth meter (Hondex Digital Depth Sounder 41114303) was used to determine the depth of every sampling location. The water surface sampling points, which start from point A and end at point B (refer Figure 1) were chosen to monitor the contamination progression due to the distance of the from the inlet source. The depth sampling was taken for every 2 meter depth. Table 1 shows the sampling point, the length from inlet point A, the coordinate and the depth.

2.2. Method of Sampling Collection and Preservation

Water samples and sediments were collected using a 250 mL laboratory glass container. The glassware was rinsed three times with distilled water and was rinse with sample water at the site before use as sample container. All samples (water and sediments), were preserved under icepack and stored in an icebox before transported to laboratory for ex-situ analysis and heavy metal analysis.

Table 1: Coordinate and depth of the sampling location

Sampling point	Length from water inlet	Coordinate	Depth
1	(50m)	N 04°43.999 E 103°11.005	7.2m
2	(150m)	N 04°43.998 E 103°11.060	7m
3	(250m)	N 04°44.000 E 103°11.114	7.4m
4	(350m)	N 04°44.001 E 103°11.165	7.6m
5	(450m)	N 04°44.004 E 103°11.220	6.2m
6	(550m)	N 04°44.006 E 103°11.272	6.2m
7	(650m)	N 04°44.018 E 103°11.329	4.7m
8	(750m)	N 04°44.025 E 103°11.380	6.2m
9	(850m)	N 04°44.032 E 103°11.434	7.2m
10	(950m)	N 04°44.038 E 103°11.488	8.6m
11	(1050m)	N 04°44.047 E 103°11.541	8.6m
12	(1150m)	N 04°44.058 E 103°11.594	9.4m
13	(1250m)	N 04°44.064 E 103°11.649	10m
14	(1350m)	N 04°44.069 E 103°11.703	11m

2.3. Samples Analysis

The in-situ measurements of the samples were carried out immediately after the samples were collected from the sampling point. The parameters measured were the electrical conductivity using a conductivity meter (Hach HQ40d), the dissolved oxygen (Ohaus Starter 300D), temperature and pH using pH meter (Ohaus Starter 300).

2.4. Statistical Analysis

Statistical analysis was conducted by one-way ANOVA using Excel –One Way Anova Analysis Toolpack 2010. It is a statistical tool as calculating a number of means and variances, dividing two variances and comparing the ratio to a handbook value to determine statistical significance to confirm and develop a description for the observed data [18].

3. Results and Findings

Statistical analysis has been done by using Excel –One Way Anova Analysis Toolpack 2010. The range, mean and standard deviation of in situ measurement parameters within seasonal change are as shown in Table 2 while the following Table 3 shows the Interim National Water Quality Standard (INWQS) and Table 4 is the result from One Way ANOVA.

Table 2: Range, Mean and Standard Deviation for Four Parameters

Parameter	Normal Season		Wet Season		Dry Season	
	Range	Mean (SD)	Range	Mean (SD)	Range	Mean(SD)
pH	2.96 – 4.32	3.19 ± 0.35	2.80 – 4.40	3.03 ± 0.33	2.85 – 3.88	2.87 ± 0.31
Temp. (^{o}C)	30.80 – 33.0	31.68 ± 0.61	27.2 – 32.3	30.68 ± 0.94	20.4 – 28.2	26.31 ± 1.69
Cond. (µScm^{-1})	242.0 – 306.0	291.00 ± 9.96	695.00 – 833.00	754.00 ± 34.04	665.00 – 759.00	693.00 ± 21.10
DO (mg/L)	5.75 – 14.39	9.50 ± 1.96	1.91 – 7.53	5.04 ± 1.93	6.25 – 10.33	8.78 ± 0.75

Table 3: Interim National Water Quality Standards for Malaysia (INWQS) [19]

Parameter	Classes					
	I	IIA	IIB	III	IV	V
pH	6.5 -8.5	6 – 9	6 – 9	5 – 9	5 – 9	-
Temperature (^{o}C)	-	Normal + 2^{o}C	-	Normal + 2^{o}C	-	-
Conductivity (µS/Cm)	1000	1000	-	-	6000	-
Dissolved Oxygen (mg/L)	7	5 – 7	5 – 7	3 – 5	< 3	< 1

Table 4: ANOVA result for four parameters

Parameter	F	P-value	Result
pH	6.15	0.0028	Significant
Temperature (^oC)	250.20	0.0000	Significant
Conductivity (μScm^{-1})	4682.81	0.0000	Significant
Dissolved Oxygen (mg/L)	88.79	0.0013	Significant

With respect to Interim National Water Quality Standards (INWQS) for Malaysia in Table 3, the mean value for pH of all three seasons fall under Class V, temperature Class I, conductivity Class I, dissolved oxygen Class I for normal season, Class IIA/IIB for wet season and back to Class I in dry season. The National Water Quality Standards or INWQS, which is applied to surface waters, ordains standard values of 72 parameters in 6 water use classes. It is divided into 5 classes which is Class 1 as the cleanest normally conservation of natural environment, Class IIA is water supply II where conventional treatment is needed , Class IIB is recreational use with body contact, Class III is water supply III where extensive treatment required and Fishery lll - common, of economic value, and tolerant species livestock drinking, Class IV is for irrigation and Class V is highly polluted water where none of the uses of the other classes can be applied to the water [19].

Table 4 shows an analysis of variance for four parameters, pH, temperature, conductivity and dissolved oxygen. Based on p-value, the statistical analysis shows that all in situ parameters measured in this study have significant differences ($P<0.05$) between three seasonal change (normal, wet and dry).

Normal value range for temperature of surface waters are usually 0° C to 30° C. The mean values of water temperature recorded for Tasik Puteri, Bukit Besi are in the range between 30.8^{o}C to 33°C for normal season, 27.2ºC to 32.3ºC in the wet season and significantly drop in dry season in the range of 20.4ºC to 28.2ºC. However it still within normal range [19]. The lowest value of temperature is recorded in the dry season probably due to less flow of water and low depth of the water body. However the trends is deviated from the trends recorded in the study of [20] that estimate the water temperature at the surface will increase by 0.01 and 0.75 °C in summer.

By looking at the trend of the mean value for pH and temperature, normal season is 3.19, wet season is 3.03 and dry season is 2.87 and the same trend is observed for the temperature. Relationship between pH and temperature can be represented in the following figure 2.

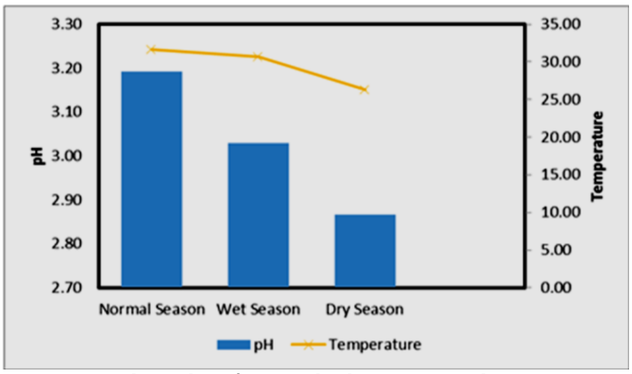

Fig. 2: Relationship of mean value between pH and temperature

The most significant data that can be seen from Figure 2 is pH, which clearly shows that the lake is extremely acidic. The lake water is acidic might be due to tailings from ex-iron mining [21] and a sign of acid mine drainage was formed indicated that the lake is contaminated with heavy metal. The value of pH is directly proportionate to the value of temperature. Those variations in water quality parameters were mainly due to seasonal changes (normal, wet or dry season). The following figure 3 shows the trend between pH and electrical conductivity based on the mean of three different seasons.

3.4.1. Figure captions

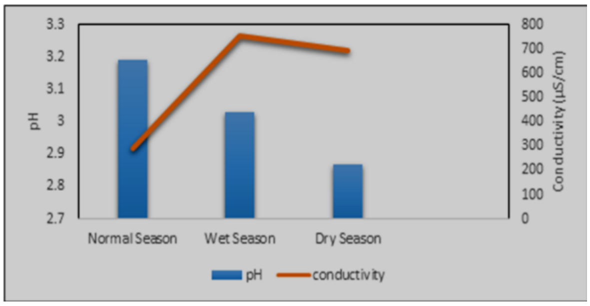

Fig. 3: Relationship of mean value between pH and conductivity

For the three different season, the average values of pH is seen dropped indicating that the water quality of Tasik Puteri also drop significally while water conductivity seems fluctuated from the beginning to the end of sampling seasons. In the study of acid mine drainage at active and abandoned mine sites in Pahang, stated that pH influenced inversely proportional to the value of electrical conductivity [22]. However in this study, two seasons show the same trend while another one season shows contradiction results compared to the study of [22]. The degrade value of pH which is recorded in the dry season in 2017 might be due to the reactivate of the mining process at the hill of Bukit Besi in the early year of 2017, which is located at the upstream area of Tasik Puteri. Low pH value is mostly associated with the discharge of heavy metal from mining industry into the surface water [20], [24-25]. According to [20], peat swamp water (flowing into the catchment) and also by metal and sand mining activity are among the factors that contribute to acidic pH and low DO. It is the result of pyrite-containing rock oxidizes and produces sulfuric acid and dissolved iron, consequently dissolve other metals contained in the rock. This is likely to be the factor that contributes to low pH in Tasik Puteri, Bukit Besi. And over the years, this may lead to high concentrations of Zn (150 mg/L) and Cu (up to 170 mg/L) in the pore water near the surface of the tailings followed by visibly precipitation of greenish eriochalcite ($CuCl_2{\cdot}2H_2O$) on the tailings surface, as observed in other chloride-rich environments [26]. However, at Tasik Puteri, Bukit Besi, only water can be seen as blue greenish with the brownish precipitation can be spotted on the plants at the river bank of the lake.

The electrical conductivity (EC) values represent high concentration of total dissolved solids. From the above figure, the value of EC indicates low value at normal season, which is August 2016, probably due to no active mining site by that time. During the wet season, the EC value increase and the main source of high EC value is the recent iron ore mining activity going on in the study area. The following figure 4 shows the trend of mean value between temperature and dissolved oxygen.

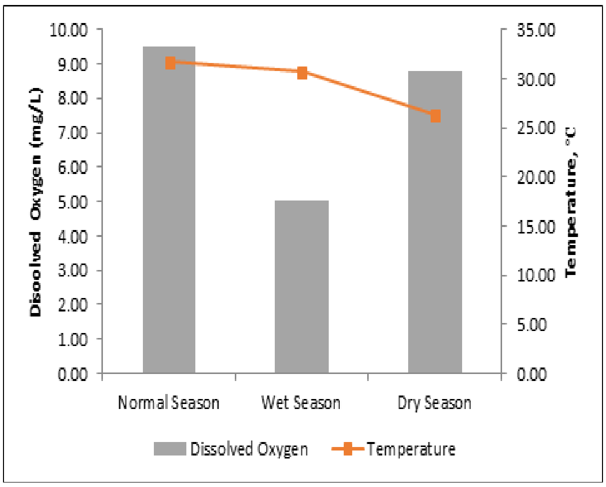

Fig. 4: Trend of mean value for dissolved oxygen and temperature

Capacity of water to hold dissolved oxygen is depend on water temperature and atmospheric pressure. Warm water at low atmospheric pressure hold less DO compared to cold water at high atmospheric pressure. It can be seen from figure 4 that DO is directly proportionate to temperature at normal and dry season and inversely proportionate at the wet season. As temperature increase, the solubility of oxygen and other gases will decrease [21 - 27]. Only wet season follow this trend but still in the value of healthy dissolved oxygen. Even though all seasons show that DO is more than 5 mg/L as been stated in [23] and [27] as a good supply of oxygen for aquatic life, ironically there is no existence of aquatic life can be seen in this lake. The low value trend of DO in the wet season show the similar trend as in the study of [6] that stated the low DO level is observed in lake Chini and lake Bera, Malaysia due to flooded water or wet season. The following Figure 5 shows the relationship between temperature and conductivity.

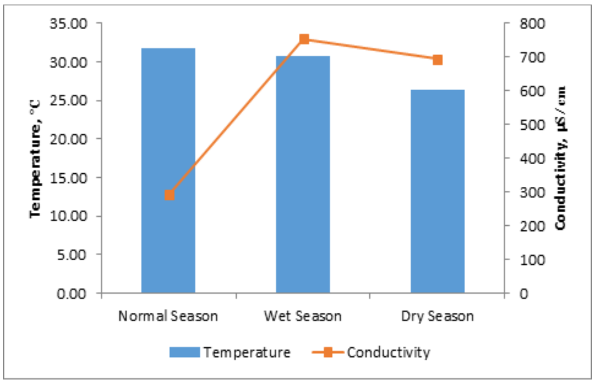

Fig. 5: Relationship between mean value of temperature and conductivity

There is two ways of how conductivity can be affected by water temperature, either by mobility of ions in less viscosity of fluid or concentration of soluble salt [28]. As shown in figure 5, conductivity in wet and dry season is directly proportional to temperature as more salt soluble in warm water but different trend is shown in normal season. The low value of conductivity recorded in normal season might be an indicator of less mobility of ions in the lake by the year of 2016 since the mining area is not reopen yet by that time. Highest conductivity is expected during the wet season as the same trend is observed in the study of [29] which stated that rainfall events can have a remarkable effect on the concentrations of ions and total dissolved solids (TDS). However, the findings of this study do not support the previous research that stated the absolute values and the range of the oscillations of electric conductivity are much higher than during the summer or dry season [30].

3. Conclusion

Overall this lake is in Class V category where the pH parameter was recorded above the limit of Interim National Water Quality Standard (INWQS) for the three seasons which is not save for human consumption. This study also indicates that reactivate of mining activities at the upstream area of Tasik Puteri brought a significant drop in the water quality. Considering future development of the Tasik Puteri as an ecotourism destination, the water quality of the lake should be improved further.

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