WATER QUALITY ASSESSMENT OF BUKIT MERAH RESERVOIR, PERAK

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Abstract

Multiple land conversions such as oil palm plantation, land clearing and sand mining activities are currently occurring at Bukit Merah Reservoir (BMR). This study was conducted to assess the current status of eutrophication at BMR and the potential use of nitrate stable isotopes technique to trace the sources of nitrate in surface water. This study was conducted in December 2016. A total of 10 sites were selected for water sampling analysis of pH, dissolved oxygen, total dissolved solid (TDS), total phosphorus, chlorophyll-a and secchi disc. The physico-chemical parameters and nutrient analysis were measured by using YSI multi-parameter and HACH DR2800 spectrophotometer respectively. The samples were transported back to the laboratory for further analysis. The result of chlorophyll a showed eutrophic condition in the middle area of BMR. Further study will incorporate the potential application of nitrate stable isotopes to traces the sources of nitrogen pollution at BMR which may enhance our understanding on how eutrophication might occur in BMR.

Keywords: Bukit Merah Reservoir, eutrophication, nutrients, physico-chemical parameters, dual-stable isotopes.

INTRODUCTION

Freshwater lakes and reservoirs play vital roles as important water resources for domestic drinking water supply, irrigation, agricultural and industrial purposes. Lakes and reservoirs provide provisioning services such as freshwater supply, fisheries and aquaculture, hydroelectric power generation, flood mitigation, recreational and ecotourism sites which contributes towards the transformation of the socio-economic in these inland water bodies [1]. The growth of human population and urbanization surrounding lakes and reservoirs trigger the expansion of the land-use activities within these water bodies. Uncontrolled land-use activities could impact the water bodies through the runoff from the agricultural areas or anthropogenic impacts that might increase the nutrients loading.

Lakes can be influenced by external inputs to the water bodies either by the organic or inorganic pollutants and nutrients loading which can deteriorate the water quality [2]. Eutrophication refers to the substantial increase of essential biological elements needed by plants, including nitrogen and phosphorus, which increase the productivity of the aquatic organisms [3]. Excessive nutrients loading will result in adverse impact of eutrophication phenomenon of the water bodies. The nutrients present in environment in the least quantity relative to plant demands for growth could limit the plants yield [4, 5]. Nitrogen (N) and phosphorus (P) are both limiting factors of plant growth in which excessive inputs of N and P will cause eutrophication.

The source of pollutions can be classified into point sources which include discharge from municipal sewage treatment plant and industrial plant while non-point sources include runoff from agricultural areas and atmospheric deposition. Urban and agricultural runoff arising from rainfall, irrigation and precipitation are non-point pollution that resulted from non-point discharge [6].

A desk study by NAHRIM [2, 7] on the status of lakes eutrophication in Malaysia has classified 90 lakes in Malaysia into mesotrophic and eutrophic condition respectively. Out of those 90 lakes, 34 lakes or 38% were evaluated to be in mesotrophic condition while another 56 lakes or 62% were in eutrophic condition including Bukit Merah reservoir. Using the Trophic State Index (TSI) values, computed by adopting the land use and total phosphorus (TP) relationships [2], assessed these lakes status. On the other hand, another study [9], showed that the water quality of BMR is classified in Class II based on the Water Quality Index (WQI) and has an intermediate level (mesotrophic) status based on the TSI value. Hence, this study focuses on analysing the current status of eutrophication at BMR and to evaluate the potential use of the stable nitrate isotopes techniques to trace nitrogen pathways in BMR.

Sampling sites

Bukit Merah Reservoir (BMR) is known as the oldest man-made lake in Malaysia, which is between the latitude of 100° 39’ 14.7” E and longitude of 5° 01’ 06.8” N. The capacity of the reservoir is equal to 70 million m^3 at 28.50 feel [8]. The BMR is located at the northern state of Perak in Peninsular Malaysia was built in 1902 for Kerian Irrigation Scheme. The main purposes of BMR were to provide the irrigation water for double cropping to 24000ha of paddy land in district of Kerian, domestic and industrial water supply of the populace in the Kerian and Larut Matang district [9]. Apart from that, BMR also supports the ecotourism planning through the lakefront resort and water park (Bukit Merah Laketown Resort) and as a tool for flood and drought control.

BMR is divided into two section of northern part and southern part by a railway-line around 4.7 km [8]. The water sources for the north area is mainly through Sg. Merah while for the south area is Sg. Kurau. The upstream of Bukit Merah is known as Batu Kurau area. Around 46.29% of land uses around BMR include virgin and primary forest, and 42.80% is dominated by agriculture (palm oil plantation) and breeding farming industry of national Boer breeding centre for economical purposes [10, 11, 12]. 10 sampling stations as in Table 1, (St 1, St 2, St 3) were established from the upstream and midstream of Sg. Kurau which eventually feeds into BMR while (St 4, St 5, St 6, St 7, St 8, St 9, St 10) were sampling stations within the waterbodies of BMR (Figure 1) in December 2016.

Table 1. Sampling stations with coordinates in Bukit Merah Reservoir

Name of station	Approximate sampling location	Description of station
1 (Batu Kurau)	04°54.618'N/100°49.913'E	Upstream of BMR
2 (Sg Kurau)	05°0.662'N/100°43.865'E	Known as one of the main catchment area/inlet to BMR
3 (Confluence)	05°0.714'N/100°43.840'E	Meeting point of Sungai Ara and Sungai Kurau
4 (Railway)	05°2.224'N/100°39.879'E	Located near the railway and consider as the upper Northern area
5 (Sg Kurau mouth)	05°1.918'N/100°40.355'E	Located at the inlet of Sungai Kurau basin
6 (Midpoint 1)	05°1.777'N/100°39.757'E	Located at the middle area of Northern BMR
7 (Dam 2)	05°1.829'N/100°39.108'E	Located near to the spillway of BMR and village
8 (Midpoint 2)	05°1.144'N/100°40.007'E	Located at the middle area of Southern BMR
9 (Water gate)	05°1.078'N/100°39.242'E	Located near to the Watergate of BMR
10 (Orang Utan)	05°0.739'N/100°40.348'E	Located near Orang Utan Island and consider as the Southern area.

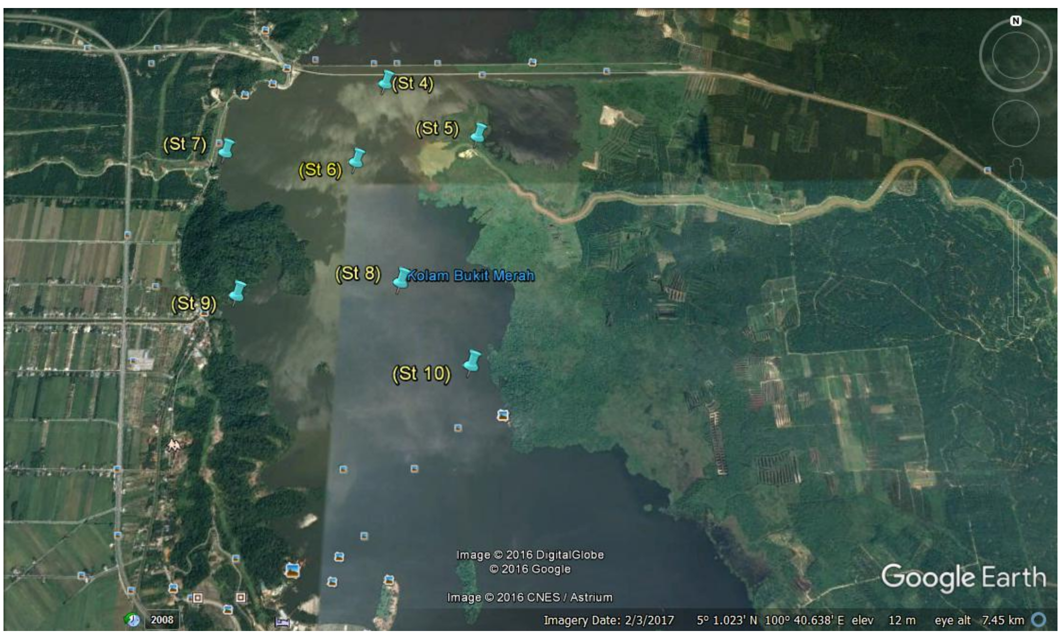

Figure 1. Sampling locations of Bukit Merah Reservoir, Perak the St 4 – St 10 indicates the sampling sites.

MEASUREMENT OF PHYSICO-CHEMICAL PARAMETERS AND NUTRIENT ANALYSIS

Physico-chemical readings were taken in three replicates *in situ* at each sampling stations. Dissolved oxygen (DO), temperature (°c), conductivity (µS/cm), pH and total dissolved solid (TDS) were measured by using YSI multi-parameter probe and water clarity by using the Secchi disc with measuring tape. A total of 20 surface water samples were collected in 500 ml and 120 ml of HDPE acid washed bottles at each sampling stations. Water samples were filtered (0.45µm) and stored at 4°c. The chlorophyll a samples were wrapped with the aluminium foil and kept in dark till the analyses were conducted. All the nutrient samples were transported back to the laboratory and stored under the same temperature for further analysis. Laboratory analysis for total phosphorus (TP) was determined by PhosVer 3 with Acid Persulfate Digestion Method while chlorophyll a was determined by using method by Adams (1990) and both followed the colorimetric method (HACH DR2800). The nutrient analyses were done within 24 h after sampling activities for the best results.

RESULTS AND DISCUSSIONS

The physico-chemical parameters, DO, pH and TDS are compared with National Water Quality Standard to see the class of the lakes from the ranged of the reading obtained. DO and pH were in class II while TDS was in Class I respectively. Class I and II indicate that the lake is suitable as water supply, fisheries activities and any recreational use [13]. However, the result from TSI evaluation indicates that BMR is eutrophic, implying nutrient rich, which may experience algae blooms or macrophyte issues, increasing the possibility of having poor water quality.

Based on the results from Table 2, the TSI for chlorophyll a alone is within the range of 14.8 µg/L to 68.16 µg/L,which falls between eutrophy and hypereutrophy as TSI attributes in Table 3. At this stage, the blue-green algae usually dominates, algal scums and macrophyte problems are present in the waterbodies. From our physical observation, the waterbody within BMR catchment area did not appear to be covered by greenish colour, thus suggesting that the waterbodies are not dominated by any blue-green or green algae on the surface water. Not all harmful algae bloom will cause water discoloration as some species such as the chlorophyll-free dinoflagellates *Pfiesteria piscicida* , several *Dinophysis* species, and benthic microalgae (e.g., *Gambierdiscus*) has no visible color [14]. The phytoplankton bloom can be brown or gray and not all red or can be no color at all [15].

The TSI for TP alone ranged from 75.41 µg/L to 93.17 µg/L while transparency (secchi depth) was recorded between 63.2 to 76.9 m. Neither transparency nor TP can be the independent estimators of trophic state as the changes in transparency caused by changes in algal biomass and total phosphorus may or may not be strongly related with the algal biomass itself [12]. From the results, the lowest transparency was measured at St 4 and St 8 where both sampling stations are located at Sg. Kurau mouth and BMR water gate. The sand mining activities through dredging projects or removal of the sediment near the Sg Kurau mouth was reported as one of the main sources that have contributed to the re-suspended sediment at the surrounding area [16]. Higher turbidity was triggered by the unsustainable sand mining activities along Sungai Kurau might be the major cause of sediment associated nutrients input [17]. The highest value of TP was measured at St 2 at Sungai Kurau area. 93% of the sediment input and nutrients in the catchment were claimed to originate from Sungai Kurau by previous researchers [9, 10, 8, 18].

Table 2. Physico-chemical parameters and nutrient parameters from surface water samples collected at 10 selected sampling stations within BMR water catchment (mean±sd)

	Temp. (°c)	DO (mg/L)	TDS (mg/L)	Cond. (μS/cm)	pH	secchi depth (m)	TP (μg/L)	Chl-a (μg/L)	TSI (Chl-a)	TSI (TP)	TSI (Secchi depth)
St 1	23.5±0.01	6.9±0.31	0.009±0.00	13.3±0.58	7.6±0.34	n/a	180±0.01	2.2	38.33	79.03	n/a
St 2	28.4±0.50	6.5±0.06	0.013±0.00	22.3±0.58	8.3±0.09	n/a	480±0.00	16.4	58.04	93.17	n/a
St 3	27.8±0.00	5.7±0.26	0.013±0.00	21.0±0.00	8.4±0.11	0.39	190±0.00	30.0	63.96	79.81	46.4
St 4	33.5±0.08	6.2±0.08	0.009±0.00	17.0±1.00	7.9±0.01	0.74	150±0.01	0.2	14.81	76.40	55.7
St 5	28.1±0.01	6.5±0.22	0.011±0.00	18.0±0.00	8.1±0.13	0.46	190±0.01	13.0	55.8	79.81	48.8
St 6	32.4±0.74	6.1±0.37	0.01±0.00	16.7±0.58	7.9±0.14	0.32	200±0.00	27.0	62.93	80.55	43.6
St 7	31.2±0.09	6.6±0.62	0.009±0.00	17.7±0.58	8.5±0.23	0.31	150±0.00	13.0	55.8	76.40	43.1
St 8	29.9±0.23	6.2±0.20	0.01±0.00	17.7±1.15	8.2±0.19	0.80	160±0.00	46.0	68.16	77.33	56.8
St 9	30.42±0.03	6.2±0.09	0.01±0.00	18.0±1.00	8.3±0.08	0.33	180±0.00	36.0	65.75	79.03	44.0
St 10	30.14±0.04	6.7±0.06	0.01±0.00	17.3±0.58	8.3±0.10	0.33	140±0.01	36.0	65.75	75.41	44.0

*Temp. is temperature, Cond. is conductivity, Chl-a is chlorophyll a, TP is total phosphorus, TSI is trophic state index.

Table 3. Trophic State Index (TSI) classification [19].

TSI	Chl a (μg/L)	SD (m)	TP (μg/L)	Attributes
<30	<0.95	>8	<6	Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion
30-40	0.95-2.6	8-4	6-12	Hypolimnium of shallower lakes may become anoxic
40-50	2.6-7.3	4-2	12-24	Mesotrophy: Water moderately clear; increasing probability of hypolimnetic anoxia
50-60	7.3-20	2-1	24-48	Eutrophy: Anoxic hypolimnia, macrophyte problems Possible
60-70	20-56	0.5-1	48-96	Blue-green algae dominate, algal scums and macrophyte Problems
70-80	56-155	0.25-0.5	96-192	Hypereutrophy: (light limited productivity). Dense algae and macrophytes
>80	>155	<0.25	192-384	Algal scums, few macrophytes

CONCLUSION AND POTENTIAL APPLICATION OF NITRATE STABLE ISOTOPES

The inland water bodies can eventually be affected by ageing process, which later results in eutrophication [1]. However, human induced activities through land use changes around the catchment area could lead to eutrophication through excessive inputs of limiting nutrient. The TSI value of chlorophyll a classified the BMR as eutrophic, which differs from the previous study which showed the mesotrophic status of BMR [9]. To answer the questions whether BMR is facing cultural or natural eutrophication, another step should be taken to investigate the possible source and factors that may lead to eutrophication problems in BMR. Besides phosphorus, nitrogen in nitrate form is another major reason to eutrophication in the catchment [19]. Excessive nitrogen in nitrate form could lead to nitrate pollution.

Atmospheric deposition, nitrogenous fertilizers, animal manure, domestic sewage discharge and soil organic nitrogen (SON) are the possible sources of nitrate in ecosystem. Hence, the effective management of nitrate contains through the identification of actual sources of N in aquatic ecosystem is needed to preserve the water quality and understanding the process affecting the local nitrate concentration [20]. The application of dual isotopes of NO_3^- is widely applied in order to trace the sources and understand the N cycle [21, 22]. Through this application, using both $\delta^{15}N\text{-}NO_3^-$ and $\delta^{18}O\text{-}NO_3^-$, can provide more conclusive source information which is based on the wide range of $\delta^{18}O\text{-}NO_3^-$ in atmospheric deposition, nitrogenous fertilizer and SON respectively [21]. From previous studies, this is a highly reliable technique for tracking nitrate sources [23].

ACKNOWLEDGEMENT

This study was funded by the Malaysian Ministry of Education and Universiti Sains Malaysia (Fundamental Research Grant Scheme (FRGS) grant no: 203/PTEKIND/6711467) and IAEA grant CRP F32007 (grant no: 304/PTEKIND/650819/I111). The author would like to thank Kerian District Department of Irrigation and Drainage for their hospitality during our sampling activity.

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