International Journal of Engineering & Technology, 7 (3.23) (2018) 5-10

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

An Overview on Water Quality Trending for Lake Water Classification in Malaysia

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Abstract

Lake water is important to all life and surroundings with multiples benefits and forms either in natural or man-made conditions. One of the most well-known tools for assessing the water quality is Water Quality Index (WQI) and widely used including Malaysia. Lake water quality should be represented in lucid way like other surface water regarding to the WQI standards for water quality assessment on lakes. This paper aims to review on lake water quality classification and its uses based on WQI standards in Malaysia. In this review, the uses of WQI for assessing the lake water and functioned of lakes are discussed. Results on pH from 5.0 to 9.2, BOD in mg/l from 0 to 180, COD in mg/l from 5 to 150, SS in mg/l from o to 1800, DO in mg/l from 0 to 8 and AN in mg/l N from -1 to 26. Variety of numbers is due to different loading of pollutions and location. With used of WQI on lake water quality assessments, further action can be taken for the uses on water resources by maintaining the quality. It also will broaden the uses of lake water as alternative of water resources in Malaysia.

Keywords: *Lake water, water characteristics, water quality.*

1. Introduction

This Generally lakes functioned as thermal structures, habitats for organisms and support food chain also playing an important role also as nutrient providers to marine life [1]. Lake water is one of the surface water sources play an important role as basic water resources as water is needed for the whole life of human beings and associated activities [2], [3].

As time change, development and population has increased the number of pollutant released into water bodies and deteriorating the quality and ecological system [4], [5]. Lake also affected with the change that comes from anthropology or natural factors [2]. Lake is important as a part of water resources both in quality and quantity of water as water also needs by various human sector such drinking water supply and irrigation [6].

Model in water quality monitoring first introduced by Horton in 1965 [7] before upgraded into various methods by experts such [8]–[10]. Other than WQI scales, monitoring of the water quality also can be based on Interim National Water Quality Standards (INWQS) for Malaysia [11], also ecological model methods for water quality prediction [12]. WQI scales provides simples scales by making collection data into single index value which denoting the water quality condition level [5]. In Malaysia, guidelines of WQI are enrolled by Department of Environment of Malaysia (DOE) based on six (6) major parameters which are dissolved oxygen (DO), pH value, biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS) and ammonical nitrogen (AN) [5]. Through the classification, water will be grouped as 'clean', 'slightly polluted' and 'polluted' if the standards complies within the range of 81 to 100%, 60 to 80% and 0 to 59%, respectively [13].

As there is no any national standards or guidelines upon lake water, classification on water assessment for the lake water mostly are based on DOE's WQI standards as the lake water are associated as surface water [14]. Focus in this paper is looking on the trending of water characteristics in several lake also the use of lakes from Malaysia spectrum.

2. Lake Water Characteristics

Lake water characteristics in Malaysia still depending on DOE's WQI tools as there are no any national guidelines on lake water in Malaysia and it classified as surface water. Putrajaya is one of the states in Malaysia has their own lake water guidelines. Characteristic for lake water on Putrajaya guidelines goes into physical, microbiological constituents, radioactivity, and organics indicators [14], [15].

Practiced on WQI as part of water quality monitoring have been done previously in several studies by [2], [16]–[18]. Some studies also comes with several others parameters such electrical conductivity (EC), redox potential (Eh), resistivity, salinity, temperature, sulphate, phosphate, oil and grease and hardness [6], [18], [19].

In water assessment, evaluation for lake water are made on three main factors that widely used where are physical, chemical and biological expressions for water classification and used [20]. All the parameters will present as a step of evaluating the watercourse

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structures and quality of the aquatic structures. Significant of the parameters will denoted good qualities of water thus make it maintain on allowable limits [21].

Parameters used are related with each other's in water quality assessment and must considered together with all the parameters are highly variable with time as impacts from natural and human factors [22]. Also play as basis for environment impact assessment report (EIA) for any water bodies, pollution load tagging also designation of class of water uses under National Water Quality Standards for Malaysia (NWQS) [23].

Lake water characteristics have been reviewed in this paper on trending of water quality index as tools on water classification. Data was obtained from several studies was shown in Table 1. From Table 1, the values from different study sites were showed that variety of reading for each parameter. Studies at Sri Serdang Pond [4] only taking three main parameters while others are not which focusing on biological oxygen demand (BOD), suspended solid (SS), and ammonical nitrogen (AN).

The parameters at that area are the most critical parts in assessment as the load was received by the pond heavily polluted by organic loading from agriculture. In Miri, Sarawak by [19], replacement of BOD, COD, DO and AN parameters by using others which is electric conductivity (EC), salinity, resistivity, redox potential (EH), temperature and total dissolved solid (TDS). Used of electrochemical parameters rather than WQI methods through the water quality assessment for degree of pollution in the pond gauged for major ions, metals and organic compound at Miri City lake. The causes of the change of values in Table 1 are influenced in few ways such hydrological, geological, climatic change, land use, and human factors [2], [3].

Fluctuation resulting on parameters influenced in few ways such hydrological, geological, climatic change, land use, and human factors [2], [3]. In 2008, reported by [28] that causes may forms as volcanic plate movement and sedimentation of plate boundary. Land use or land cover affecting the water bodies such discharge from commercial areas, domestic waste water and agricultural waste [27], [29]. Climatic change such erosion due to high intensity of rain at certain time and the water runs on the soil has turned the quality to change as effect from the rain activity [20].

Total of free hydrogen and hydroxyl ions measured in pH, will show how acidic or alkaline the water [30]. The findings in this study ranging from 5.0 to 8.0 of scales means the water goes to alkaline condition. Patterns of the scales caused by influent loads by outsides such industries activities, agricultural area, and natural factors [2], [3]. If the range of pH either below than 5.0 or higher than 8.0, the water quality should be taken into account as acidic or alkali condition and not suitable for the water supply [23].

BOD was 0 to 180 mg/l shown in Table 1 earnings that the needs on oxygen for biological degradation is getting low when total number of BOD is getting high. From the classification of water use, the category of water also changed with most of the category in Class IIA until Class V. Only some location in Chini Lake [25] classified in Class I. Table 2 shows the water classification for water use based on National Water Quality Standard (NWQS) for Malaysia culture.

For COD value, concentrations only recorded at Klang River Basin [24], Chini Lake [25], Skudai Watershed [27], and Cempaka Lake [18]. The rest of location are unavailable of data. Compared with the NWQS permitted value, Klang River Basin are in Class V, Chini Lake between Class I until Class III and same goes to Skudai Watershed and Cempaka Lake at Class IIA. High value of COD in the results as caused by released of the organic matters into the streams as near to the commercial areas.

Table 1: Water characteristics based on WQI on several lakes

Location	Water Quality Index (WQI)					
	pH	**BOD (mg/l)**	**COD**	**SS**	**DO**	**AN**
Miri City [20]	7.24	N/A	N/A	N/A	N/A	N/A
Sri Serdang Pond [5]	N/A	180	N/A	750	N/A	26
Klang River Basin [25]	6.8 – 8.0	40	150	1800	8	-1 - 15
Chini Lake [26]	5.0 – 8.0	0 – 4.5	6 - 50	0 - 13	0 - 8	0.01 – 0.3
Klang Valley and Melaka [27]	3.4 - 9.2	1.3 – 6.0	N/A	≤ - 6.0	1.5 – 6.4	0.09 – 0.24
Skudai Watershed [28]	5.8 – 7.0	3.0 – 24.0	5 – 47	29 – 144	3.4 – 13.3	0.1 – 7.2
Cempaka Lake [19]	6.79 – 7.01	3.41 – 3.56	24.07 – 30.30	25.76 – 45.16	2.58 – 3.82	2.71 – 3.68

N/A: Not Available

Table 2: National Water Quality Standards (NWQS) for Malaysia [14]

Parameter	Class						
	Unit	I	IIA	IIB	III	IV	V
pH		6.5-8.5	6-9	6-9	5-9	5-9	-
DO	mg/L	7	5-7	5-7	3-5	<3	<1
BOD	mg/L	1	3	3	6	12	>12
COD	mg/L	10	25	25	50	100	>100
SS	mg/L	25	50	50	150	300	300
AN	mg/L N	0.1	0.3	0.3	0.9	2.7	>2.7

Description

Class I	Conservation of natural environment Water supply – Practically no treatment necessary Fishery I – Very sensitive aquatic species
Class IIA	Water supply II – Conventional treatment required Fishery II – Sensitive aquatic species
Class IIB	Recreational use with body contact
Class III	Water supply III – Extensive treatment required Fishery III – Common of economic value and tolerant species; livestock drinking
Class IV	Irrigation
Class V	None of the above

SS (suspended solid) always containing of matter in solid states and suspended in water, consist of organic and inorganic matters such plankton, silt, and industrial waste [24]. In Semenyih river basin, total suspended solid (TSS) was caused by human factor at one of their location near to construction also soil erosion from riverbank as impact from rain. Soil erosion also taking into account as suspended solid as they are coming from surrounding due to human activities [3]. Reported in Cempaka Lake [18], stated that source of organic and inorganic matters into the lakes were caused by erosion pollution where dredging activity happened there.

The higher number of DO in the water means higher ability of aquatic life to be in the water bodies. When the value is low, may cause death to the organisms. A study on Chini Lake [25] shown that nutrients leaching from agricultural effect has affected the water bodies through flourishing of microorganisms and algae decomposition thus affecting pH value.

Ammonical nitrogen (AN) any toxic pollutant that normally came from waste products and landfill leachate such sewage that may form in the water bodies [24]. All reviewed data shown AN value with range -1 to 26. Between -1 to 26 of total AN, most of the data are over the permissible guideline as the different sources of load pollution which been discharged into the water bodies.

Studied by [18] shown that causes at of presence the AN value at Cempaka Lake were sewage discharge as the sources were coming from residential area and local village at the upstream of the water flow into the lakes. Numbers of AN in Table 1 were quite dangerous as low as -0.01 and highest at 26. Some of the lake studies are safe while other were slightly polluted and polluted. Presence of the AN value normally caused by untreated domestics discharge, agricultural, and livestock activities [18], [27].

Dissimilar in each data from studies above are impact from various load of pollutions loads. Also within all the parameters, all are inter-related. The load also affected by various ways which may come from man-made or natural impacts.

3. Lake Formations

Lakes formations are variety and from perspectives of [32], lakes can be divided into 11 types of conditions which is; tectonic lake basins, lake basins produced by volcanic activity, lake basins produced by land sliding, lake basins produced by the action of glaciers, lake basins produced by the dissolution of the bedrock, lake basins formed by fluvitile process, lake basins formed by shorelie processes, lake basins formed by wind action, lake basins formed by organic accumulation, lake formed by the impact of meteorites, lake basins formed by human activity.

Arrangements in lakes formation can be either natural or man-made where natural arrangements are surrounded by river basins can lakes can occur anywhere. Normally, in natural types of arrangements, it lies within wetlands, marshes, estuarine lakes. For man-made lakes, it forms as reservoirs, retention pond, examining pond, recreational lakes and for urban landscape functions [14].

Different in Malaysia, most of the lakes are coming from swamp wetlands and only few are in natural forms. Not only depending on natural forms or swamp wetlands, artificial or man-made lake also constructed based on needs and function to fulfill the nation needs [33].

In addition, for man-made lakes in Malaysia, it is estimated that around more than 4,000 of ex-mining lakes, which covered around 16,000 hectares (ha). Man-made lake in Malaysia begun from various activity such former mineral mining such tin ore and iron, flood control, reclamation, hydropower, irrigation, water supply, and silt retention [14], [34].

In general, it seems that lakes might be from natural or man-made activity but the use of lake remained the same. With large of numbers man-made lakes in Malaysia, it can be manipulated into other function for the future use.

4. Functions of Lakes in Malaysia

Natural or man-made lakes gave us a same return in functions to surroundings. It served a various ways of function such water supply, irrigation, hydropower generation, flood mitigation, food chain, navigation, medium transportation (such boating), and eco-tourism [14], [20], [33].

The important roles as 90 percent of nation's water supply comes from lakes and reservoir in Malaysia and has served for water for domestics, industrial and agricultural, fisheries and flora and fauna. Bukit Merah Lake in Perak, classified as natural lakes has become a habitat for fisheries sector for exotic marine life which is Malayan Gold Arowana fish (Scleropages formosus) that high in price for full grown fish. It means that lakes also home or habitat of variety biological life and freshwater fish sector [14]. Kenyir Lake in Terengganu, Pergau in Kelantan, Batang Ai and Bakun in Sarawak, Temenggor in Perak also Pedu and Muda Lake in Kedah were some of the man-made lakes that function as reservoir [14].

As summarized [14] from inventory of lakes and reservoir in Malaysia, purposed of lakes goes into water supply, irrigation, hydropower, flood control, reclamation, silt retention, natural, and ex-mining pool. Reflecting from the water quality assessment, the quality will provide a lake status before taken into decision for any use purposed.

5. Comparative between Lake Water and Raw Water

Raw water and lake water as a part of watercourses where lake water still classified as surface water as they are connected with river basins. The use of water quality index (WQI) in Malaysia and linked to the Interim National Water Quality Standard of Malaysia (INWQS) are used as a classification or correlation for water use of watercourse for any purposes based on the outline by the standards [14], [23]. Other than using WQI, the classification lake water also can be done using trophic state index (TSI) [35].

Acting as freshwater sources, lake water contained unwanted particles that needs to be clean to work as an alternative for water supply [36]. As a part of water sources, correlation between both of raw and lake water normally analyzed in Malaysia are based on physical-chemical parameters where it replicates the land use forms as physical characteristics of the surroundings which are fixed [20]. Several studies by [2], [3], [5], [23], [37] have reveal that there were a relationship between raw and lake water parameters have been done.

Reported by [5] in Terengganu river basin, the studies resulting on water quality index through six parameters listed by DOE are measured. Quality of the water were changing from slightly polluted to clean with percentage of WQI ranging from 71.5 to 94.6% which means the water uses was very good for supply without further treatment and can be used for very sensitive species for conservation. In Perak, at Bukit Merah reservoir, [23], contents of the water quality in the reservoir based on WQI index and some heavy metals contents has shown a variety of results. With application of WQI tools, it was classified that the water quality were slightly polluted in Class III with average number of 75.63. However, water from this reservoir is needs to be cleaner for the raw water supply and accepted for outdoor used with this standards.

Sembrong Dam reservoir [2], is among of the dam that serve for raw water supply in Johor. At this point, the implementations of the water quality standards with heavy metals parameters are used such copper (Cu), lead (Pb), chromium (Cr), ferum (Fe) and zinc (Zn). The classification of the water at this dam is based on Interim National Water Quality Standard of Malaysia (INWQS). Indications from the results obtained shown that the quality of water are not polluted with heavy metals since the reading are below the permitted value and the some others parameters are classifieds in Class I, Class IIA, and Class III. With this value of category, further improvements are needed from this reservoir for raw water supply. Relationship between raw and lake water have shown a significant sign the needs of classification to maintain the quality of water at permitted value of loading for the next use.

6. Alternatives Use of Lake Water as Supply

As a part of water supply network, total of water generated from the lakes more than 30 billion cubic meters can be supply with total covered area from lake in Malaysia is more than 100,000 hectares (ha). Table 3 shows the lake numbers in all states in Malaysia excluded ox-bow lakes and ex-mining ponds that existing in Malaysia and surroundings area [14].

Studied by [14] was stated that raw water data from inventory of lakes and reservoir in Malaysia, able to use for water supply. Table 4 was summarized on some of the lake in each state in Malaysia there were lot of potential in supplying the water to the users.

Almost all of the lake stated in the table has a large quantity of water in their storage. As function on lake also variety and depending on the lake area, lake water can be concluded as an option for water supply after river. In the Table 4, can be concluded that each of the lake in Malaysia has an ability to become a water supply points to the consumers as the total contents of the water in lake is high. Some of the lakes sources or systems consist of two rivers which mean that high of water are supplied into the lakes.

The sources of water that enter into the lake mainly from river either single or multiple of sources. It is apparent from this Table 4 that almost all lake sources are coming from single river network and several lake are in multiple network either two or three network sources. Strong evidence from river networking which flow into the lakes shows that the quantity of the water in the lake always maintained.

Despite with high in storage capacity and lake status between bad and moderate, some of the lakes are still function as water supply sources also after being used also for other function such irrigation and hydropower energy. With area covered by lake and quantities of water, possibilities of water supplies on fulfilling the demand on water use in Malaysia can be overcome as Malaysia are getting developed each year.

On lake status, Trophic State Index (TSI) is used on nutrient loading determination from land use with total phosphorus (TP) relationship. TSI will graded the status of water as 'good', 'moderate', and 'bad' through Carlson's TSI values. Referring to the classification, terms 'good' with value of TSI below than 37.4, between 37.4 and 47.4 is 'moderate' and over than 47.4 is 'bad'[14]. None at all in good terms but most of the lake quality were in moderate and bad condition. Causes of the condition are mostly due to algal blooms and water weeds. Eutrophication with algal blooms and water weeds caused the disturbance on water and quality of water. TSI is different from WQI as TSI only on phosphorus, nitrogen and other biological nutrients which can be consumed by organisms.

With most of the lake use were water supplies, potential to become another option for supply is high. The uses of TSI index on lake status measurement also determine the level of eutrophication on the lake water. As possibilities for supplies are there, further actions are needed for better water quality before supplies to the user.

Table 3: Lakes and reservoirs in Malaysia [15]

States	Numbers	Area (km^2)	Volume (Mm^3)
Perlis	2	13.33	40.00
Kedah	7	95.03	1,637.76
Perak	11	284.68	6,766.50
Selangor	15	11.38	511.32
Pahang	10	94.69	355.71
Kelantan	4	11.34	76.80
Johor	13	84.22	940.02
Labuan	3	0.50	5.40
Melaka	4	8.75	81.30
Negeri Sembilan	5	2.25	182.33
Penang	4	0.94	47.20
Sabah	5	1.81	29.61
Sarawak	4	97.08	6,080.00
Terengganu	2	370.80	13,600.00
Putrajaya	1	7.50	45.00
Total	**90**	**1,094.89**	**30,398.95**

7. Conclusions

Factors influencing the lake water quality around Malaysia came from two major factors which is natural and anthropology or man-made causes. Process of natural factors is around us such hydro-geological impacts, climate change, geological such rain and temperature. As impact from the rain, has caused the soil erosion. Biggest challenge is man-made factor such industrialization, urbanization, pollution, dredging caused the erosion worst and make it shallow. Water Quality Index (WQI) practiced in Malaysia enforced by authority of Malaysia mainly with six major parameters on water quality monitoring.

Parameters in this study are also influenced on time and natural effects also inter-related. AN value mostly from all studies location are in Class V with value are over than 2.7 mg/L N with highest value of AN is 26. DO value mostly grouped into Class III and IV between 3.82 until 13.3. For SS, there is a Class I till IIA categorized as range from 0 to 29, Class III at 144 while other are in Class V from 750-1800. In COD group, range from 5 to 50 for Class III and 150 on Class V. As BOD are sensitive parameters, the data classified on Class I to Class III from 0 to 4.5 and 40 to 180 are in Class V. While pH parameters, good quality of water classified on 6.79 to 8.0 at Class 1, below than 5 or over 9, the data are not classified and refer as dangerous.

Total of water quantity also numbers of lakes is high; potential on lakes to become as water supplies is bright. Most of the function of lakes on data provided shown almost all the lake in Malaysia was used for water supplies. Functions of lakes to works on water supplies supported by the relationship between the raw water and lake water. The used of WQI guidelines aided by INWQS also TSI tools will provide a systematic ways on maintaining the lake condition on nutrients loading.

Overall, most of the lake studies were in moderate status and only certain lakes in bad status as parameters values over the guidelines. WQI also can be used in lake systems as lake also classified as one of the water sources parts and can be used together with INWQS. For further action on water use, some of the lake water needs further action before can be supplies to the users.

Table 4: List of lake function for water supply [15]

State	Lake	River system/ sources	Area of lake (km^2)	Storage capacity (Mm^3)	Lake status	Lake use
Perak	Bersia	Sg. Perak	5.7	70	Bad	W, FL
	Bukit Merah	Sg. Kurau	41	75	Bad	I, W
Selangor	Batu	Sg. Kelang	2.5	36	Moderate	FL, W
	Klang Gates	Sg. Kelang	2.25	28.51	Moderate	FL, W
Pahang	Anak Endau	Sg. Anak Endau	7.2	38	Moderate	I, W
	Pontian	Sg. Pontian	20	40	Bad	I, W
Kelantan	Pergau (Kuala Yong)	Sg. Pergau	4.3	14.3	Moderate	H, FL
	Bukit Kuang	Sg. Kuang/ Sg. Kelantan	4.04	4.3	Bad	I, W
Johor	Bekok	Sg. Batu Pahat	8.75	32	Bad	FL, W
	Congkok	Sg. Tenglu	0.5	0.954	Moderate	W

Kedah	Malut	Sg. Malut	0.5	7.16	Bad	W
	Muda	Sg. Muda	26	120	Moderate	I
Labuan	Bukit Kuda	Sg. Bangat	N/A	4.78	Bad	W
	Kerupang	Sg. Kerupang	N/A	0.21	Bad	W
Melaka	Air Keruh	Sg. Melaka	0.5	N/A	Bad	RE
	Asahan	Sg. Kesang	0.75	0.7	Bad	W
Negeri Sembilan	Kelinci	Sg.Kelinchi/ Sg. Pahang	N/A	50	Bad	W
	Pedas	Sg. Beringin/ Sg. Linggi	N/A	0.525	Bad	W
Pulau Pinang	Air Hitam	Sg. Air Hitam/ Sg. Pinang	0.25	2.6	Moderate	W
	Mengkuang	Sg. Mengkuang/ Kulim/ Perai	0.625	23.6	Bad	W
Perlis	Timah Tasoh	Sg. Perlis	13.33	40	Bad	I, W, FL
	Tasik Melati	Sg. Perlis	N/A	N/A	Bad	RE
Sabah	Babagon	Sg. Babagon	N/A	21.5	Moderate	W
	Sepagaya	Sg. Silibukan	N/A	2.5	Moderate	W
Sarawak	Batang Ai	Sg. Batang Ai	N/A	2800	Moderate	H
	Sika (Bintulu)	Sg. Sika	N/A	3280	Moderate	W
Terengganu	Kenyir	Sg. Terengganu	369	13600	Bad	H, FL
	Puteri/ Bukit Besi	Sg. Paka	1.8	N/A	Bad	EM,RE
Putrajaya	Tasik Putrajaya	Sg. Chua/ Sg. Langat	7.5	45	Moderate	RE

N/A: Not Available, Note: H: Hydropower; W: Water Supply; I: Irrigation; FL: Flood; FD: Food; RE: Reclamation; EM: Ex-Minin

Acknowledgment

The research for this paper was financially supported by the Post-graduated Research Grant (GPPS) of Universiti Tun Hussein Onn, Malaysia with Vot Project No. U942. In developing the ideas presented here, I have received helpful input from Dr Sabariah Musa, the audiences and editors for their feedback. Without which the present study could not have been completed.

References

[1] N. G. Hairston and G. F. Fussmann, Lake Ecosystems, *eLS*, 2014.
[2] S. Mohd-Asharuddin, N. Zayadi, W. Rasit, and N. Othman, Water Quality Characteristics of Sembrong Dam Reservoir, Johor, Malaysia, *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 136, no. 1, pp. 6–12, 2016.
[3] F. Al-Badaii, M. Shuhaimi-Othman, and M. B. Gasim, Water Quality Assessment of the Semenyih River , *J. Chem.*, vol. 2013, no. 5, pp. 31–34, 2013.
[4] N. Abdillah and T. Y. Fang, Water quality assessment of Sri Serdang Pond , Malaysia, in *IAHR, WORLD CONGRESS*, 2014, no. September 2013, pp. 1–18.
[5] S. Suratman, M. I. Mohd Sailan, Y. Y. Hee, E. A. Bedurus, and M. T. Latif, A Preliminary Study of Water Quality Index in Terengganu River Basin, Malaysia, *Sains Malaysiana*, vol. 44, no. 1, pp. 67–73, 2015.
[6] M. B. Gasim *et al.*, Water Quality Degradation Of Cempaka Lake , Bangi , Selangor , Malaysia As An Impact Of Excessive E . Coli And Nutrient Concentrations, *Malaysian J. Anal. Sci.*, vol. 19, no. 6, pp. 1391–1404, 2015.
[7] R. K. Horton, An index number system for rating water quality, *J. Water Pollut. Control Fed.*, vol. 37, no. 3, pp. 300–306, 1965.
[8] H. Inhaber, An approach to a water quality index for canada, *Water Res.*, vol. 9, no. 9, pp. 821–833, 1975.
[9] J. M. Landwehr and R. A. Deininger, A comparison of several water quality indexes., *Water Pollut. Control Fed.*, pp. 954–958, 1976.
[10] D. G. Smith, A better water quality indexing system for rivers and streams, *Water Res.*, vol. 24, no. 10, pp. 1237–1244, 1990.
[11] Department of Environment, *Malaysia Environmental Quality Report 2006*, 2007th ed. malaysia: sasyaz holdings sdn bhd (219275v), 2006.
[12] E. Kianirad, D. Bedoya, K. Mcgarvey, and V. Novotny, Review of Watershed Ecological Models Center for Urban Environmental Studies Review of Watershed Ecological Models Student Investigators, 2006.
[13] Department of Environment, *Malaysia Environmental Quality Report 2008*, 2009th ed. malaysia: sasyaz holdings sdn bhd (219275v), 2008.
[14] Y. F. Huang, S. Y. Ang, K. M. Lee, and T. S. Lee, Quality of Water Resources in Malaysia, *Res. Pract. Water Qual.*, 2015.
[15] A. R. Abdullah Baginda, Putrajaya Lake & Wetland : Water Quality Status, 2013. [Online]. Available: http://www.mwa.org.my/events/20130205/6. Dr Rani -Putrajaya-seminar 2013v4.pdf. [Accessed: 10-Apr-2018].
[16] N. N. N. Daud, A. Abdulrahman, and S. Idrus, Preliminary Assessment Of Lakes Water Quality Status At Campus Area In Selangor, Malaysia, *Malaysian J. Civ. Eng. 28*, vol. 49, no. 1, pp. 42–49, 2016.
[17] N. A. S. Mohamad Sabri, P. Abdullah, and S. Mat, Monitoring and Assessment of Water Quality of Tasik Cempaka, Bangi, *AIP Conf. Proc. 1614*, vol. 342, pp. 1–6, 2014.
[18] N. A. S. M. Sabri, M. P. Abdullah, S. Mat, R. Elfithri, and W. M. A. W. M. Khalik, Evaluation of Hydrochemistry Variation in Water Quality of Cempaka Lake , Malaysia using Multivariate Statistical Analysis, *J. Mater. Environ. Sci.*, vol. 7, no. 12, pp. 4403–4410, 2016.
[19] M. V Prasanna, R. Nagarajan, A. Elayaraja, and S. Chidambaram, Preliminary Investigation on Electrochemical Parameters of Lake Waters in and around Miri City , Malaysia, *Pertanika J. Sci. Technol. 22*, vol. 22, no. 1, pp. 329–335, 2014.
[20] M. S. Islam, B. . Ismail, M. B. Gasim, A. Sahibin, and T. EKhwan, Hydrological Assessment and Water Quality Characteristics of Chini Lake, Pahang, Malaysia, *Agric. Environ. Sci.*, vol. 12, no. 6, pp. 737–749, 2012.
[21] B. Daniela, C. Borda, and R. Bucur, Physical , Chemical , and Biological Parameters in the Quality Assessment of Natural , Changed and Created Water Ecosystems, *Bull. USAMV-CN*, vol. 2006, no. 63, pp. 24–30, 2006.
[22] N. Cleophas, F. Isidore, L. Ka Han, and K. Bidin, Water quality status of Liwagu River, Tambunan, Sabah, Malaysia, *J. Trop. Biol. Conserv.*, vol. 10, no. April, pp. 67–73, 2013.
[23] C. O. Akinbile, M. S. Yusoff, S. H. Abu Talib, Z. Abu Hasan, W. R. Ismail, and U. Sansudin, Qualitative analysis and classification of surface water in Bukit Merah Reservoir in Malaysia, *water Sci. Technol. water supply*, vol. 13.4, no. 13.4, pp. 1138–1145, 2013.
[24] I. Mohamed, F. Othman, A. I. N. Ibrahim, M. E. Alaa-Eldin, and R. M. Yunus, Assessment Of Water Quality Parameters Using Multivariate Analysis For Klang River Basin , Malaysia, *Environ. Monit. Assess.*, vol. 186, no. november 2014, pp. 1–12, 2015.
[25] A. Md. Yasir, M. S. Islam, M. Abdul Karim, Z. Abd Wahid, and E. Abd Aziz, Characterization Of Chini Lake Water Quality With Malaysian WQI Index Using Multivariate Statistical Analysis, *bangladesh J. Bot.*, vol. 46, no. 2, pp. 691–699, 2017
[26] I. B. Koki, K. H. Low, M. Abdul Zali, A. Azid, and S. Md Zain, Consumption of water from ex-mining ponds in Klang Valley and Melaka , Malaysia : A health risk study, *Chemosph. 195*, vol. 195, no. 195, pp. 641–652, 2018.
[27] I. Naubi, N. H. Zardari, S. M. Shirazi, N. Farahen, B. Ibrahim, and L. Baloo, Effectiveness of Water Quality Index for Monitoring Malaysian River Water Quality, *J. Environ. Stud.*, vol. 25, no. 1, pp. 231–239, 2016.
[28] S. F. Murphy and R. F. Stallard, Primary Factors Affecting Water Quality and Quantity in Four Watersheds in Eastern Puerto Rico,

Third Interag. Conf. Res. watershed, no. september 2008, pp. 8–11, 2008.
[29] A. A. R. O, N. D. N. N, A. Amimul, and B. Pradhan, Water quality assessment of UPM Lake and the impact of geographic information system, *Int. J. Environ. Monit. Anal.*, vol. 2, no. 3, pp. 158–162, 2014.
[30] A. A. Abdul Latiff, *Syarahan perdana 2011 water pollution : the never ending story*, First edit. Malaysia: Penerbit Uthm, 2011
[31] D. Tomas, Č. Mirjana, and A. Senta, Assessing the surface water status in Pannonian ecoregion by the water quality index model, *Ecol. Indic. J.*, vol. 79, no. April, pp. 182–190, 2017.
[32] P. G. Â. Ş. Tescu, Limnology , Lake Basins , Lake Waters, *Lakes, Reserv. ponds*, vol. 3, no. 1, pp. 7–12, 2009.
[33] Z. Sharip and S. Zakaria, Lakes and Reservoir in Malaysia : Management and Research Challenges, *Proc. Taal2007 12th World Lake Conf.*, no. 1, pp. 1349–1355, 2008.
[34] M. A. Ashraf, M. Jamil Maah, and S. Yusoff, A new fill material technology for ex-mining land reclamation and construction purposes, *Fresenius Environ. Bull.*, vol. 21, no. 5 A, pp. 1334–1343, 2012
[35] R. E. Carlson, A trophic state index for lakes, *Limnol. Oceanogr.*, vol. 22, no. 2, pp. 361–369, 1977.
[36] J. Jaromír Klemeš *et al.*, Water Purification of Lake Water Using Progressive Freeze Concentration Method, *Chem. Eng. Trans.*, vol. 56, pp. 43–48, 2017.
[37] M. B. Gasim, M. E. Toriman, S. A. Rahim, M. S. Islam, C. T. Chek, and H. Juahir, Hydrology , water quality and land-use assessment of Tasik Chini ' s feeder rivers , Pahang , Malaysia, *Malaysian J. Soc. Sp. 2*, vol. 2, no. 1999, pp. 72–86, 2006