

WATER QUALITY ISSUES IN WATER RESOURCES MANAGEMENT AT KENYIR LAKE, MALAYSIA

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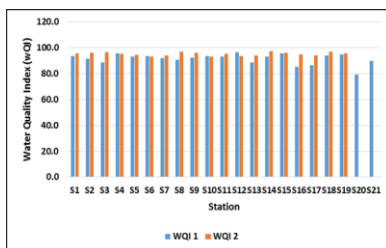
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Graphical abstract



Abstract

Water resources management in Malaysia is the most important aspect that needs to be addressed. When water resources management can be managed in a systematic and effectively it can produce a good quality and clean water without any pollution. The objective of this study is to review water quality issues in the Kenyir Lake Basin and to identify the relationship between river discharges (Q) and the water quality status in Kenyir Lake Basin. Six water quality parameters were analyzed based on in-situ and ex-situ analysis and laboratory analyses were carried out according to the correlation matrix and linear regression methods. According to the NWQS, the water quality in Kenyir Lake Basin varied temporally and spatially and the most affected parameters were pH, DO, BOD, COD, TSS and AN. Furthermore, the water quality class in the Kenyir Lake Basin was classified under class II caused by the active land use activities especially tourism sector but it is still suitable for recreational activities and safe for body contact because the its WQI is not less than 65% which early stage of Class II. From this study, there are proposed several mitigation measures in management of water resources such as guarantee clean water supply and continuous, implementation a few of environmental acts, treating the water sources, develop alternative water sources and improve distribution systems and water management.

Keywords: Water resources management, pollution, environmental acts, mitigation measures

Abstrak

Pengurusan sumber air di Malaysia adalah aspek yang paling penting yang perlu ditangani. Apabila pengurusan sumber air dapat diuruskan secara sistematik dan berkesan, ia dapat menghasilkan sumber air yang berkualiti dan bersih tanpa pencemaran. Objektif kajian ini adalah untuk mengkaji isu kualiti air di Lembah Tasik Kenyir dan mengena lpasti hubungan antara luahan sungai (Q) dan status kualiti air di Lembangan Tasik Kenyir. Enam parameter kualiti air dianalisis berdasarkan analisis *in-situ* dan *ex-situ* dan analisis makmal dijalankan mengikut matriks korelasi dan kaedah regresi linear. Menurut NWQS, kualiti air di Lembangan Tasik Kenyir berubah-ubah secara temporal dan spatial serta parameter paling terjejas adalah pH, DO, BOD, COD, TSS dan AN. Selain itu, kelas kualiti air di Lembangan Tasik Kenyir diklasifikasikan di bawah kelas II yang disebabkan oleh aktiviti penggunaan tanah secara aktif terutamanya sektor pelancongan tetapi ia masih sesuai untuk aktiviti rekreasi dan selamat untuk sentuhan badan kerana nilai WQI tersebut tidak kurang daripada 65% yang peringkat awal Kelas II. Berdasarkan kajian ini, terdapat beberapa langkah mitigasi dalam pengurusan sumber air seperti jaminan bekalan air bersih secara berterusan, melaksanakan beberapa akta berkaitan alam sekitar, merawat sumber air, membangun sumber air alternatif dan memperbaiki sistem pengedaran dan pengurusan air.

Kata kunci: Pengurusan sumber air, pencemaran, akta alam sekitar, langkah mitigasi

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1.0 INTRODUCTION

Malaysia are known as the developing countries. The development around river basin were give the bad implication according to changing the geometric and hydrological status of environment as the bigger pollution sources and it can influencing the river stability in Malaysia [1-4]. Water assumes a focal part in the economic, ecological, social, and also political mosaic.

The National Park Service (NPS) is to improve, rehabilitate, and propagate the characteristic normal reliability of water dependent and water resources environments that happen in the national park system. Water is very important for food, economy, human and environment. The river is the main water source for life in this world [5-7].

There 7% of the total have drained underground water and 36% have returned to the atmosphere are known as evapotranspiration [8-9]. The need for water is very widespread and it is all over the place. It also moves continuously, starting with one area to another and starts with one condition to another. Water may also be in place or everywhere. However, its use is required to include quantity, quality and accessibility [10-12].

Water is one of the most important natural resources besides air, land, and heavy metals required by all living and non-living things such as humans, animals, plants and the environment. Water is one of the most important sources to generate food sources, acts as a source of transportation, helps in the growth of animals and plants, and others [13].

Water resources have become an interaction between humans, animals and the environment. In other words, without water, various activities cannot be carried out properly and will affect everyday life. Therefore, it is a duty and responsibility for all parties to safeguard this water resource in terms of quality and quantity before it is destroyed. Water quality problems are an issue that is often around the world. For example, disposal of sewage remnants from the municipal process and the industrial sector to the irrigation system will be cause of water quality to decline and contaminate [14-16].

The report issued by the Department of Environment Malaysia (DOE, 2000) [17] found that the major causes of water quality deterioration were domestic sewage, industrialization, pork farming and agricultural-based industries. The land used around Kenyir Lake Basin can be divided into 9 types such as forest, water body, transportation and road reserves, public utilities, residential, leisure and recreation area, infrastructure and utility and industry.

The forest's area is the largest land area in Kenyir Lake with total area of 476.55 hectares and covering 52.83% of the total areas. The water body area is the second largest land use in Kenyir Lake with an area of 308.80 hectares that covering of 34.23% from the total area. The interruption of the land used area for Kenyir Lake is shown in Table 1 (Rancangan Eksekutif Rancangan Khas Tasik Kenyir, 2008 until 2020 [18]).

Table 1 Land used activities around the Kenyir Lake Basin, Hulu Terengganu, Terengganu

Landuse	Area (Hectares)	Percentage (%)
Forest	476.55	52.83
Water Body	308.80	34.23
Transportation and Road Reserves	46.81	5.19
Public Utilities	45.14	5.00
Residential	2.95	0.46
Leisure and Recreation Area	1.84	0.33
Infrastructure and Utility	15.66	0.20
Industrial	0.17	1.74
Total	902.00	100.00

Water resource management is provided for the entire human population. All water sources are made from groundwater and all water surfaces used for human consumption. Initiation of water resource framework and configuration development [19-20]. For example, dams, water treatment structures, water supply structures and evacuation structures to each other [21]. Water asset management is the most important for quality control and treatment of water resources. The accessible water sources will induce unnecessary weight due to limited countries and uncontrolled development [22].

Water should also be organized in tandem with the ultimate goal of overcoming the loss of life, the extreme danger of private and open property [16]. In that capacity, the branches of city hydrology and power through pressure within the structure building manage the outline and the legitimate arrangement of each type of control office that combines the framework of storm, simple steps of desire like inheritance and dam, the desire to plan the basic path skeleton among others [21]. Generally, water management can be categorized into three groups, where group 1 is relates to assets, group 2 about overseeing water benefits, and group 3 about dealing with the exchange expected to adapt free market activities [23].

Other than that, the second factor is pollution and climate change that causes shortage of water resources [24]. Now, almost all of the activities involve the use of machines and technology. Environmental quality, air and water become polluted due to mining process. It is therefore the responsibility of experts and stakeholders from all walks of life to come forward and further develop ideas in protecting and preserving the environment from degradation. However, until today the increase of water pollution index has become a major cause in reducing the quality and quantity of water resources. Water quality deterioration can be linked to urban and rural development activities, including sedimentation problems resulting from wind and soil erosion, nutrients from fertilizers, animal feces from livestock and septic systems, pesticides including herbicides, insecticides, fungicides and so on [25-26].

Water pollution can be divided into two main categories, which are point sources and non point sources pollution. The source of pollution points can be interpreted as any identified sources of contamination that are directly released, such as pipes, drains, vessels or processing factories [27]. For example, processing factories include oil refineries, factories, chemical factories and electronics plants that cause pollution through oil, heat pollution, chemicals, toxic and sewage treatment plants such as waste from factories and sewage treatment plants as waste products and treated wastes will be released into rivers that can cause bacterial and nutrient growth and cause polluted water sources [28]. Meanwhile, the non point sources pollution occurs from a stream. When rain or snowflakes are flowing on the surface of the earth and through the soil, clean water will absorb and mix with any contaminants when mixed [29]. For example, sources of non point sources pollution can be caused by contaminants from construction sites or from unprocessed industrial.

The huge numbers of the water issues were become very complex, interrelated and extensive to be handled by any single establishment, independent of the specialist and assets given to it, specialized ability and administration limit accessible, level of political help, and all the great aims. The definition that was planned by the Global Water Partnership (2000), which considered it as a procedure of the administration of water, organized

improvement, arrive and related assets [30]. It is to boost the social welfare and resultant financial in an impartial way without bargaining the manageability of imperious environments. In the most recent decade, the assessment of water-quality administration related with the standard of maintainable improvement has been of worry to numerous scientists and chiefs. It requires not just the support of built up standards and innovations but in additionally their expansion to substantially more high, extensive, and more liberated degree for the acknowledgment of supportability for the water quality administration [31-33]. Although, the current circumstance of water quality administration on the planet is an extensive way from agreeable. It is because of the weights of expanding populace and financial improvement [34-42].

Since 2007, the Department of Environment (DOE) has been observing the water quality. Based on the National Water Quality Standard (NWQS) and WQI, the Department of Environment (DOE) has classified lakes into a few classes such as class I, II, III, IV and V. To measure the quality of water and detect the water pollution, it is one of the indicator that can be used (Table 2). Based on 6 significant pollutants, the WQI parameters measured which is Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (AN), Total Suspended Solid (TSS) and pH [16, 43].

Table 2 National Water Quality Standards (NWQS) for Malaysia

Parameter	Class					
	Unit	I	II	III	IV	V
PH	-	> 7	6 – 7	5 - 6	<5	>5
DO	mg/L	>7	5 - 7	3 - 5	1 - 3	<1
BOD	mg/L	<1	1 – 3	3 - 6	6 - 12	>12
COD	mg/L	<10	10 – 25	25 - 50	50 - 100	>100
TSS	mg/L	<25	25 – 30	50 - 150	150 - 300	>300
AN	mg/L	<0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	>2.7
Water Quality Index (WQI) (%)		<92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	>31.0

Source: Department of Environment (DOE)

2.0 STUDY AREA AND RESEARCH METHODOLOGY

Study Area

Kenyir Lake is the biggest lake in Malaysia and this well-known fascination is situated within the territory of Terengganu. Kenyir Lake is the biggest man-made lake in South East Asia and it is located in the district of Hulu Terengganu and also spanning an area of 260,000 hectares. This lake was constructed for the purpose of generating hydroelectric power which is able to supply electricity to all state in Peninsular Malaysia. The construction of the dam around Kenyir Lake started from 1978 and was completed in 1985. The wide variations in climatic and land use impacts whereas others are much more sensitive to any environmental change. In addition, the accidental or deliberate

introduction of invasive non-native species can also severely impact communities of indigenous species in Kenyir Lake. The wide variations in climatic and land use impacts whereas others are much more sensitive to any environmental change. Increasingly, however, the anthropogenic effects of human activity such as intensive agriculture, deforestation, urbanization and tourism are causing specialized habitats to change, shrink and become fragmented to the extent that they may no longer be self-sustainable.

In addition, the accidental or deliberate introduction of invasive non-native species can also severely impact communities of indigenous species in Kenyir Lake. The management implications of this characteristic of incremental development of degradation problems and the potentially long time for lakes to respond to management interventions include the need for long term involvement of relevant lake basin management institutions and their activities. The

potential for long term impacts also suggest a need for a precautionary approach in developing and implementing lake management interventions. The collaborative research to understand the levels of resilience of such specialized environments is critical to

protecting them and making informed policy decisions about land use planning and natural resource extraction. Figure 1 showed the map location of study areas.

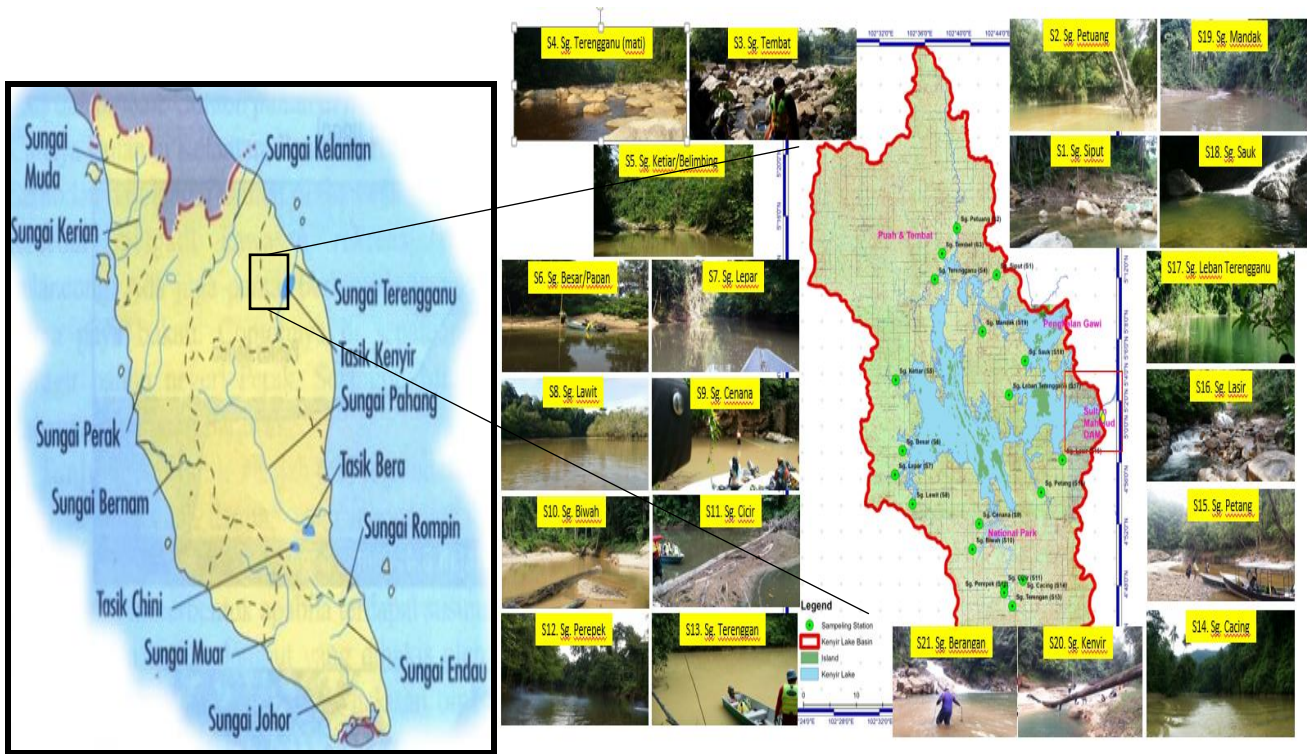


Figure 1 Map of Sampling Location at Kenyir Lake Basin, Hulu Terengganu, Terengganu, Malaysia

The distribution of mean monthly temperature recorded at Felda Belara, Hulu Terengganu from 2001 until 2017. The highest mean temperature recorded on April, May and June every year and the lowest value on January and February. Detailed relative humidity for Hulu Terengganu climatological station from 2001 to 2017. In general, relative humidity is slightly high. Relative humidity near 90% can be occurred in the mornings and during the monsoon season, because of an increase in moisture supply rather than a reduction in temperature.

Similarly, saturation deficits during the monsoon are significantly smaller than during the pre-monsoon period (August-October), being almost as small as they are during the months of March and April, when air temperature and the amount of water that can be held by air are at their lowest. The highest mean monthly humidity recorded on January and December and the lowest recorded on April and June (Figure 2).

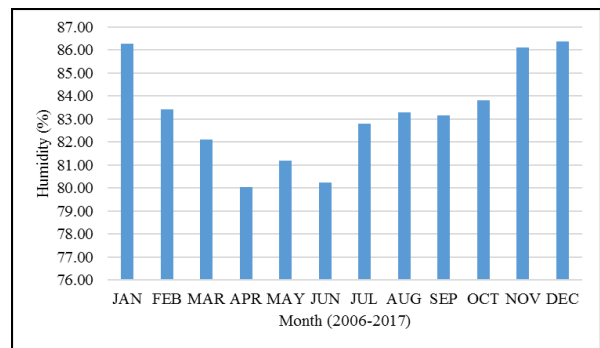
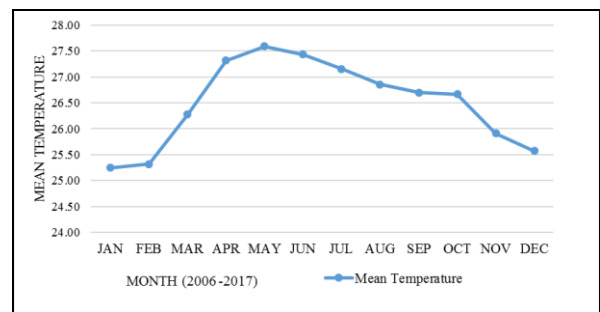


Figure 2 The Mean Monthly Temperature and Humidity Recorded at Felda Belara, Hulu Terengganu Meteorological Station (2001-2017)

2.2 Research and Methodology

Water Quality Parameter and Hydrological Analysis

All the sample preparation and preservations conducted were following on the standard procedures provided by American Public Health Association (APHA) and United States Environmental Protection Agency (USEPA) Methods [16, 44]. There six significant parameters of water quality index based on National Water Quality Standard (NWQS) such as Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH₃-N), Total Suspended Solid (TSS) and pH. Besides that, the laboratory analysis was performed based on the standard method of analysis (APHA 1998) procedure.

Statistical Analysis

The data gathered from the survey were coded and analysed using XLStat2014 licensed software for Microsoft Excel. The numerical data analysing using experimental studies and the data obtained are analysed by statistical test [14]. The statistical analysis method applied in this study such as Leave one out method based on regression analysis. Leave-one-out method or input importance were also performed to identify the most and the least significant ($p < 0.05$) variables as due to linear correlation between input-output.

3.0 RESULT AND DISCUSSION

Difference Analysis of Six Parameters by Wet and Dry Season

Based on this study, Figure 3 showed the COD, BOD, TSS and NH₃-N values in mg/L based on wet and dry seasons in the Kenyir Lake Basin. The range values of COD from 2 mg/L to 6 mg/L during wet season and from 1 mg/L to 10 mg/L during dry season. The maximum value of COD recorded in dry season as 10 mg/L (Station 16) higher than the maximum value recorded in wet season. Besides that, the maximum values of COD in wet seasons at Station 3, Station 8 and Station 18 as 6 mg/L and the minimum value at Station 11 as 2 mg/L. The BOD values analysis recorded the minimum and maximum value as 0.85 mg/L and 1.40 mg/L respectively during wet season. While during dry season showed the minimum and maximum values as 0.31 mg/L and 0.51 mg/L respectively. The density of water at forest canopy is the main role towards reducing the surface erosion which contributes to sediment load production in river basin [4]. When the

water flow in a basin increased, the TSS will also increase because the higher flow contains the strong energy to move the higher concentrated the suspended sediment load compared to the low flow level and the high water flow also increased the rate of erosion. TSS is also to determine whether the status of water quality clean, moderately polluted or contaminated and to estimate the suspended sediment load production in the Sungai Terengganu, TSS is an indicator to classify the river in Class I, II, III, IV or Class V, based on NWQS. The highest amount of TSS at Sungai Lepar and Sungai Cenana recorded 18 mg/L respectively. The minimum level amount of TSS at Sungai Besar, 4.4 mg/L during dry season. The value of TSS on dry season showed higher range compared wet season where affected by climate changes and anthropogenic factors, the TSS amount for all sampling stations were recorded 4.4 mg/L \pm 18.00 mg/L during dry season and 1.6 mg/L \pm 15.00 mg/L during wet season. From the result, the difference amount level of TSS at Kenyir Lake Basin where affected by the anthropogenic and geomorphology factors, climate changes and hydrological cycle. This study proved the wet season (higher density of rainfall) caused the higher level of soil loss. From Department of Environment (DOE) 2000 stated the WQI Class of Kenyir Lake Basin for TSS in class II during wets season, the river water needs to be treated and still suitable to protect aquatic species and recreational activities. The concentration of NH₃-N varied from 0.02 until 1.01 mg N/L (wet season) [17].

In general, higher concentrations of NH₃-N were recorded at the middle and lower parts of the basin in comparison with the upper basin stations especially during wet season. The production of NH₃-N caused by the fertilizers from agricultural areas around the outlet of Kenyir Lake Basin (Terengganu River). Figure 4 showed the range values of DO in wet season as a minimum value of 3.84 mg/L and maximum value as 8.15 mg/L while during dry season showed the minimum value as 5.37 mg/L to the maximum value as 8.53 mg/L. Figure 5 shows the pH value based on wet and dry seasons in the Kenyir Lake Basin. Results of pH value analysis performed in the dry season showed a minimum value of 7.6 to a maximum value of 8.6. Meanwhile, the measurement results in the wet season from 5.32 to the maximum value of 7.7. From the result, the trend of deteriorating water quality at Kenyir Lake Basin going from the upstream to the downstream stations. The main contributor of water quality parameters in Terengganu River Basin especially at downstream and middle stream area are COD and TSS. This is probably due to the discharge of untreated municipal, tourism, construction and domestic waste into the lake systems as these stations are situated within the heavily populated areas of Kuala Berang and a few villages around the Kenyir Lake Basin [16, 45-47].

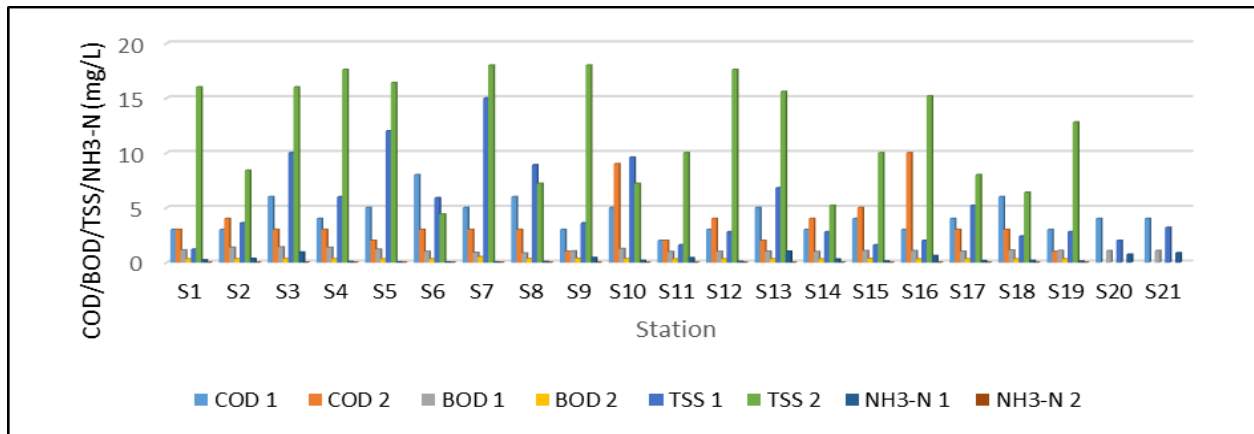


Figure 3 Variation of COD, BOD, TSS and NH3-N values for the different sampling stations at Kenyir Lake Basin

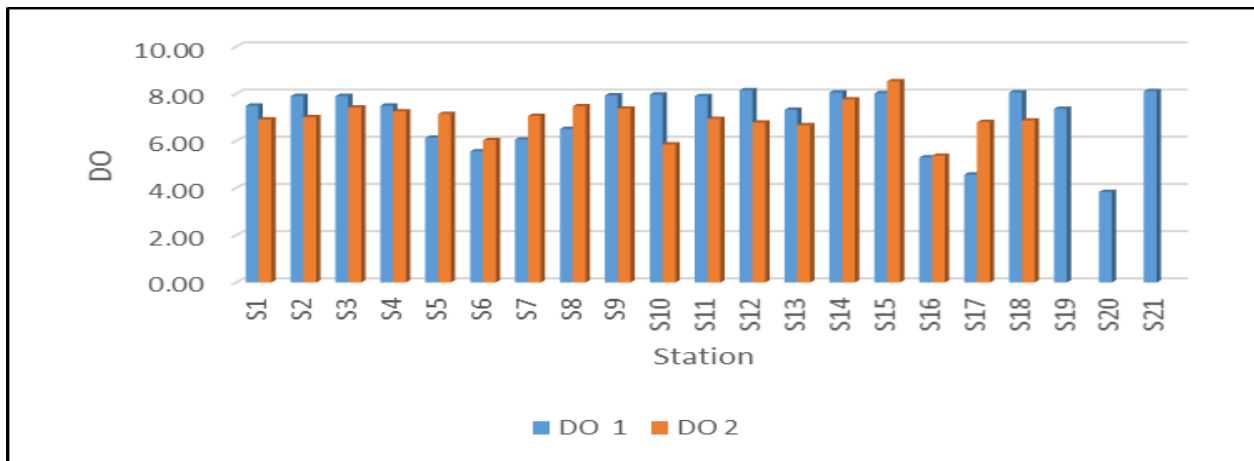


Figure 4 DO values in mg / L based on dry season and wet season at Kenyir Lake Basin

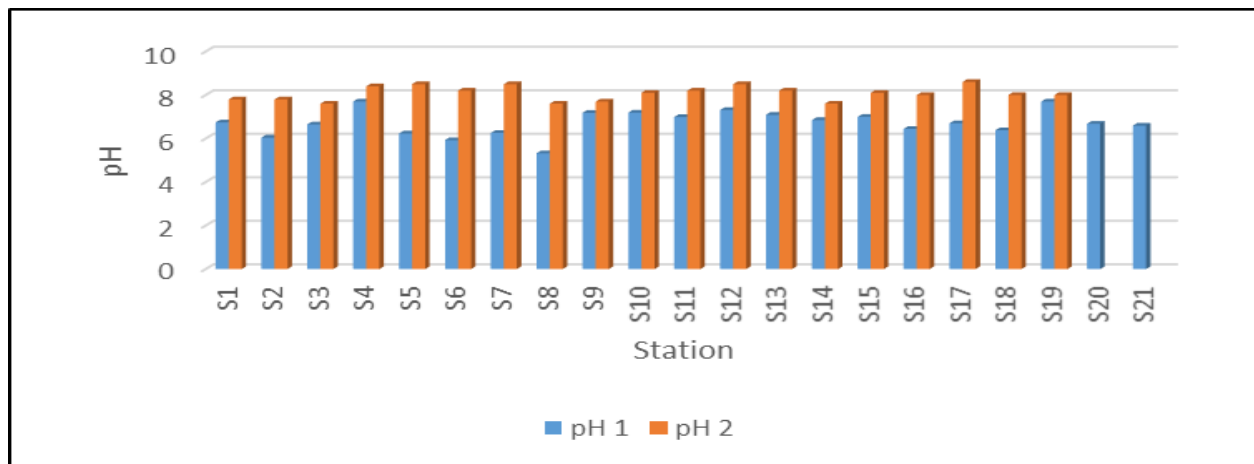


Figure 5 pH value based on wet and dry seasons in the Kenyir Lake Basin

Water Quality Index (WQI)

Water quality index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water. It is calculated from the point of view of human consumption. From the a few

preliminary water quality level studies in Kenyir Lake Basin proved there are high values of BOD, COD, TSS and NH3-N at middle and downstream areas as compared with the upstream of the lake basin. The reverses were true for the pH and DO values.

This study adopted the DOE-WQI tool to evaluate the water quality of the Kenyir Lake where affected

by hydrological characteristic and possible sources from anthropogenic activities. In addition, the beneficial use of the water was also compared with the classification based on the NWQS. Water Quality Classification Based on DOE-WQI and NWQS for Malaysia (DOE 2008) [48]. WQI is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water [16, 49-50]. It is calculated from the point of view of human consumption. Based on the DOE-WQI calculation (Figure 6), the water of the Kenyir Lake Basin (upstream until downstream)

was classified as Class II (polluted) but all stations showed WQI level not below than 60% which is suitable for recreational activities where body contact still safe. However, there are an extensive treatment required.

The management and control approach must be conducted to improve these problems before these issues become more serious as one of the conservation methods. Low water quality was found at the downstream and middle stream stations which around tourism and residential areas.

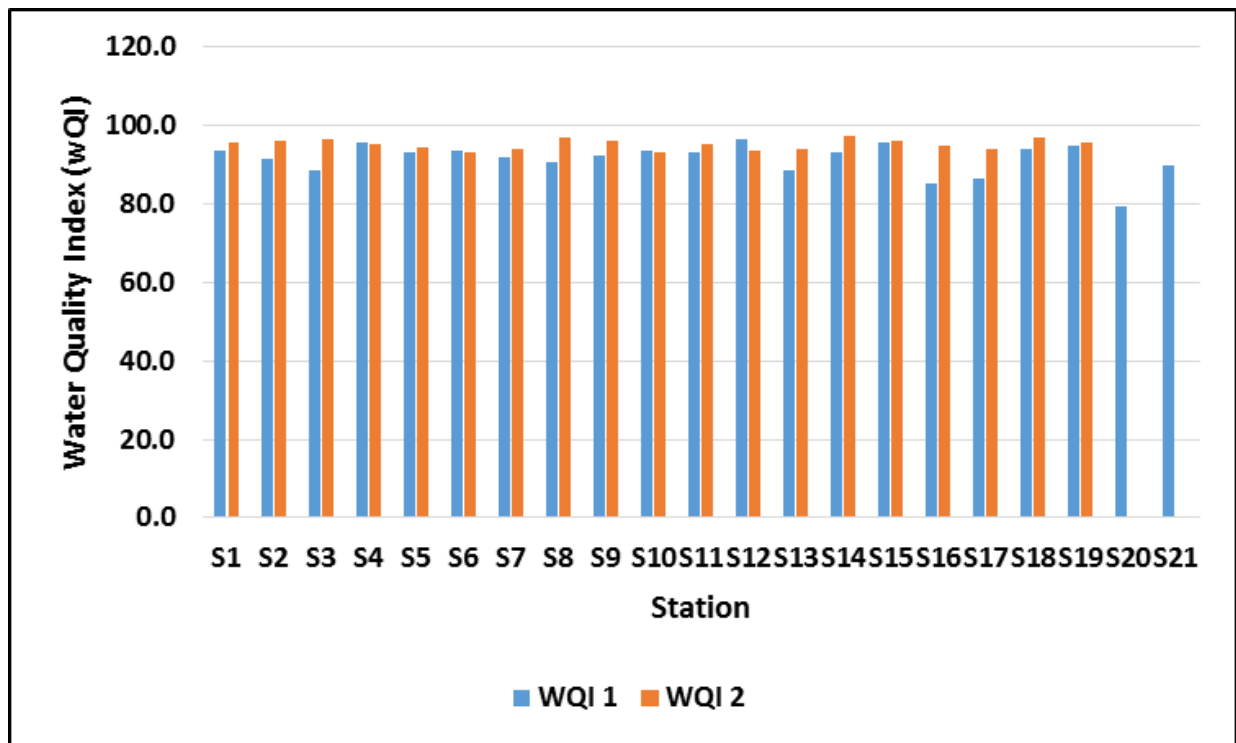


Figure 6 The Distribution of WQI at Kenyir Lake Basin during Wet Season and Dry season

Leave One Out Method

Leave-one-out method or input importance were also performed to identify the most and the least significant ($p < 0.05$) variables as due to linear correlation between input-output. Table 3 and Table 4 showed the input importance variables in linear relationship to predict WQI on Wet Season and Dry Season at Kenyir Basin. During wet season, the percent contribution of DO, BOD, COD and TSS (21.95%) which are highest than others contributors. However, the percentage of DO (53.11%), COD (20.36%) and pH (20.20%) highest contributed than others parameter during dry season. From the result, the trend of deteriorating water quality at Kenyir Lake

going from the upstream to the downstream stations. The main contributor parameter in Kenyir Lake Basin especially at downstream and middle stream area are COD and TSS. This is probably due to the discharge of untreated municipal, industrial and agricultural wastes into the river systems as these stations are situated within the heavily populated areas of Kuala Berang and a few villages around Kenyir Lake Basin. In addition, a small amount of aquaculture activities near the downstream stations influenced the results. Studies showed the wastes from these activities were characterized by high organic content leading to low pH, low DO and high $\text{NH}_3\text{-N}$ and TSS values as a result of the decomposition processes.

Table 3 An important variable in linear relationships to predict WQI in the wet season at Kenyir Lake Basin

R-Square Reference= 0.9634				
Leave Variable	R-Square Variable	Leave	R-Square Difference	Percent Contribution
DO	0.5091		0.4543	21.95
BOD	0.5091		0.4543	21.95
COD	0.5091		0.4543	21.95
NH3-N	0.7183		0.2451	11.84
TSS	0.5091		0.4543	21.95
PH	0.9560		0.0074	0.357
Total	3.7107		2.0697	100

Table 4 Important variables in linear relationships to predict WQI during the dry season at the Kenyir Lake Basin

R-Square Reference = 0.9855				
Leave Variable	R-Square Variable	Leave	R-Square Difference	Percent Contribution
DO	0.6584		0.3271	53.11
BOD	0.9822		0.0033	0.53
COD	0.8601		0.1254	20.36
NH3-N	0.9855		0	0
TSS	0.9499		0.0356	5.78
PH	0.8611		0.1244	20.20
Total	5.2972		0.6158	100

The Water Resources Management

There are many water resource management procedures in Malaysia. First, the measures of sustainable water resources management is guarantee clean water supply and continuous. The developed commercially, in particular capacity and distribution compared to consumer demand, water resource properties that have either fixed or seasonal as well as review of the Environmental Impact Assessment (EIA). To ensure continued water supply capacity in the long term, the study of hydrological elements of early is very important. If this is not done it will make problems cut off water supply will always be facing the user. Most of studies reviewed the distribution of rain intensity, input and flow rate of the river, underground water storage, topography, the climate and hydrological changes [51-53]. Policy is one of the factors in management and protection of water resources. For example, the National Environment Policy of Malaysia enacted in the Third Malaysia Plan has taken into account the importance of maintaining the quality of the environment in order to supply good water resources to the population especially in the production of agricultural, forestry, fisheries and water resources [54]. These priorities are then placed on the governments of each of their respective states to ensure that it can be used to not only support national development goals but also to help sustain the country's ecosystem. In water quality and resources management, a holistic environmental

policy approach is necessary for sustainable development. These policies describe ultimate goals to reconcile economic growth with environmental protection to achieve the sustainable environmental management. To achieve the targeted water quality certain policy changes following the law and the imperative cooperation of various government departments and agencies including but not restricted to local councils, Department of Environment (DOE), Department of Irrigation and Drainage (DID), Ministry of Housing and Local Government, Department of Forestry, Ministry of Agriculture and environmental institute [55].

The legislative approach in water quality management effected by the 1974 Environmental Quality Act makes use of Section 34A where a report on impact on the environment resulting from prescribed activities in EIA requirement is mandatory. In this act describe that any activities which are cause water pollution such as recreational development, and waste treatment, disposal facilities, tourism, construction, housing, industry, mining, petroleum, power generation and so on. From the Environmental Quality (Sewage and Industrial Effluents) Regulations 1979 required that are needed the written permission be obtained before the construction of any building or carrying out any work that may result in a new source of effluent or discharge [54, 56-57].

The uniform discharge standard is applicable throughout all countries in the world and does not take into account the assimilative capacity of a river

or water body. For the environmental protection, there is a need to develop river or stream standards and for effluent discharge standards to be set accordingly in order to comply with these river or stream standards. The Malaysian National Water Services Commission (or Suruhanjaya Perkhidmatan Air Negara, SPAN) was formed in April 2007 was established to regulate the whole of the water services industry, defined to include sewerage services, so as to promote holistic and efficient water services. These service to protect the interest of consumers of the water and sewerage services in the country.

4.0 CONCLUSION

The Natural Resources interprets conservation as "the achievement of the highest sustainable quality of living for mankind by the natural utilization of the environment." Water resources management particularly in the basins of Kenyir Lake is a very important aspect that should be noted and improved by the relevant. Water quality in the Kenyir Lake Basin was polluted due to human activities in the manufacturing sector and so on.

All stakeholders should work together in maintaining water quality and improving water resources management especially in the Kenyir Lake Basin. There are many initiatives have been implemented by the government in managing water resources in Malaysia. Among the initiative or measures undertaken by the government are improve distribution systems and water management as well as water smart campaign use to users. Besides that, authorities such as Department of Environment (DOE) need to play an important role to guide the water resources regularly. It will make water resources management in Kenyir Lake Basin can be carried out effectively and produce good quality and clean water to the community without any pollution. In this study we have proposed some measures or steps in the management of water resources in the Kenyir Lake Basin.

All of this are to make Kenyir Lake Basin provide a good quality of water and also to ensure that Kenyir Lake Basin is free from any water pollution

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