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An Integrated Assessment of Water Quality in Artificial Lakes: A Case Study of Tasik Kemajuan Using Bioindicators, Water Quality Index, and Trophic Status Index

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Abstract

Artificial lakes play a vital role in water resource management, supporting ecological balance and providing opportunities for recreation, agriculture, and urban water supplies. However, these lakes are increasingly threatened by pollution and eutrophication due to human activities and rapid urbanization, resulting in significant ecological challenges. This study examines the water quality of Tasik Kemajuan, an artificial lake located at Universiti Tun Hussein Onn Malaysia (UTHM), using a comprehensive approach that integrates bioindicators, the Water Quality Index (WQI), and the Trophic Status Index (TSI). The study conducted bioindicator analysis, focusing on macroinvertebrates, which resulted in a water quality status of Class II (clean to very clean) with moderate diversity and favorableecological conditions. The WQI results averaged between 72.87 and 73.95, classifying the water as slightly polluted (Class III), which emphasizes the need for significant treatment before use. Other than that, TSI scores ranging from 76.36 to 79.51 identified the lake as eutrophic, characterized by nutrient enrichment that leads to excessive algae growth and oxygen depletion. The findings highlight the lake's ecological challenges, particularly nutrient-induced eutrophication, while the integration of these assessment methods provided a holistic understanding of the lake's water quality. Comparative analysis of WQI, TSI, and bioindicator data demonstrated the complementary strengths of these methods, highlighting the need for an integrated approach to water quality assessment. This study highlights the importance of implementing targeted management strategies to enhance water quality and preserve ecological balance in artificial lakes.

1. Introduction

Water quality matters for irrigation, recreation, drinking water supply, and other uses for which the water is used. Physical and chemical limnology defines water quality, encompassing the biological, chemical, and physical aspects of water that affect its useful application [1]. Biological entities known as bioindicators can be used to monitor environmental quality. Given their widespread distribution, a study by [2] states that simplicity and low cost of sampling, macroinvertebrates are ideal bioindicators because of their well-known high sensitivity to an organic contaminant. Macroinvertebrates have proven to be a reliable and consistent choice for biological monitoring compared to other species. This is because they are very sensitive to organic contaminants, have a wide distribution, and are convenient and inexpensive to sample [2].

Other than that, a water quality index is a regularly used indicator for monitoring and assessing the quality of a river. Water quality index (WQI) includes classifying rivers into various ranks based on their appropriateness and uses. The WQI is an equation that combines these calculations to provide an index value representing the overall water quality state. WQI is an important index that uses, monitors, also tracks any incremental water quality improvement trends to measure the efficacy of stream restoration initiatives. According to [3], the Department of Environment (DOE) of Malaysia has established national water quality guidelines.

The Trophic Status Index (TSI) is a classification system used in civil engineering and environmental science to assess and describe the water quality of lakes, reservoirs, and other bodies of water based on their nutrient content and productivity. Developed by Robert E. Carlson in 1977, the TSI helps in understanding the ecological health of a water body and its suitability for various uses. The biological condition of a lake is the basis for single-parameter trophic state indices. This condition is influenced by several factors, including chemical variables such as nitrogen and phosphorus, as well as physical variables like light and temperature. According to conventional multiparameter index methods, trophic status is an intricate response resulting from the interplay of various biological, chemical, and physical factors [4].

2. Methodology

This methodology employs bioindicators, the Water Quality Index (WQI), and the Trophic Status Index (TSI) to assess the water quality of an artificial lake through an integrated approach involving site selection, sampling, and data analysis.

2.1 Site Selection

This study was being carried out in Universiti Tun Hussein Onn Malaysia (UTHM) lakes in Parit Raja, Johor to determine the water quality and level of eutrophication of the lakes. The *Tasik Kemajuan* was the sole subject of this investigation. It is appropriate to use this lake as a study area since it exhibits the traits of invasive aquatic plants. The plan for the UTHM lake's water flow is shown in Fig.1. The macroinvertebrates bioindicator sampling was conducted at Research Management Centre (RMC), UTHM and *Dewan Sultan Ibrahim*, UTHM as both flows of the location contributed to *Tasik Kemajuan*.

Fig.1 *The plan view of water flow of UTHM lake*

2.2 Macroinvertebrates Biological Sampling Method

Sampling macroinvertebrates as bioindicators is an effective method for assessing water quality and ecological health due to their sensitivity to environmental changes. In this study, sampling was conducted at Research Management Centre (RMC) and Dewan Sultan Ibrahim using a robust kick net with fine mesh and a collection tray. The kick net was positioned downstream in riffle areas while substrates were disturbed to collect organisms, with additional sampling targeting submerged vegetation, woody debris, and other microhabitats. Collected material was carefully transferred, rinsed, and examined to identify macroinvertebrates using field guides and microscopes, ensuring accurate documentation of species abundance. Data was analysed using the Average Score per Taxon (ASPT) to evaluate water quality, following standardized protocols and local regulations for a comprehensive assessment of the aquatic ecosystem. The score of macroinvertebrates found will be determine using Table 1.

Table 1 *Classification of animal according to score determined* [1]

Animal	Score
Nymphs	
Stonefly nymphs	10
Flattened mayfly nymphs	10
Prong-gilled mayfly nymphs	10
Spiny crawling mayfly nymphs	10
Dragonfly nymphs	6
Damselfly nymphs	6
Swimming mayfly nymphs	5
Square-gilled mayfly nymphs	4
Larvae	
Caddisfly larvae with sand/gravel cases	10
Caddisfly larvae with cases made from leaf	7
Common net-spinner larvae	5
Other caseless caddisfly larvae	10
Dobsonfly larvae	9
Beetle larvae	5
Alderfly larvae	4
Rat-tailed maggots	3
Non-biting midge larvae	2
Other fly larvae	5
Insects	
Long-mouthed saucer bugs	10
Lesser water boatmen	5
Greater water boatmen	5
Other water bugs	5
Adult bettles	5
Crustacea	
River prawns	8
Freshwater shrimps	4
Water hoglouse	3
River crabs	3
Molluscs	
Freshwater limpets	6
Swan mussels	6
Pagoda snails	6
Other snails	3
Pea cockles	3
Worms	
Flatworms	5
Leeches	3
Segmented worms	1

The score was marked according to the type, as each type was counted only once. Next, the average score was determined by adding all the scores and dividing by the number of animal types noted. It is essential to calculate an average score, as this will help mitigate any errors that may have been introduced by the sampling process. The score was then referred to the Biological Monitoring Working Party score (BMWP) in Table 2 to assess the water quality of the artificial lake.Some examples of how your references should be listed are given at the end of this template in the 'References' section, which will allow you to assemble your reference list according to the correct format and font size.

Table 2 *Biological monitoring party score [1]*

Score	Condition
7.6-1.0	Very clean water
5.1-7.5	Rather clean water
2.6-5.0	Rather dirty water-average
1.0-2.5	Dirty water
0-0.9	Very dirty water

2.3 Water Quality Index

The main purpose of analysing the physical, chemical, and microbiological characteristics of water is to determine its nutrient status. [3] states that the quality of water in lakes, reservoirs, and rivers is determined by physico-chemical and biological parameters. Besides, the water quality index provides overall water quality at a certain location and time based on multiple water quality parameters. Results of WQI in past research align with the research location in one year period will be used for comparison with data of bioindicator that been analysed. The DOE water quality classification will be determined based on Table 3 and Table 4 and discussed in terms of water quality status based on Table 5, then comparison with bioindicator results.

Table 3 *DOE water quality index classification [4]*

Parameter	Unit	Class				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 - 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 - 5	1 - 3	< 1
Ph	mg/l	> 7	6 – 7	5 – 6	< 5	> 5
Total Suspended Solid	mg/l	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)	mg/l	< 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

Table 4 *DOE water quality classification based on water quality index [4]*

Sub index & water quality index	Index range		
	Clean	Slightly polluted	Polluted
Biochemical Oxygen Demand (BOD)	91-100	80-90	0-79
Ammoniacal Nitrogen (NH3-N)	92-100	71-91	0-70
Suspended solids (SS)	76-100	70-75	0-69
Water quality index (WQI)	81-100	60-80	0-59

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Table 5 *Water classes and uses [4]*

Class	Uses
Class I	Conservation of the natural environment. Water Supply I – 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.

2.4 Trophic Status Index

The Trophic State Index (TSI) is an ecosystem-based monitoring tool that calculates a water body's nutrient base and functional productivity solely based on its physical and limnological characteristics. The Carlson Trophic State Index (CTSI) is the most employed technique for multivariate trophic indexing. It relies on the measurements of total phosphorus, chlorophyll a concentration, and Secchi disc transparency. Along with other factors connected to the aquatic environment, such as Secchi depth (SD) and total phosphate (TP), Carlson (1977) established Chla (CA) as a basic reference to characterize the trophic state [5]. The trophic classification will vary depending on the hydrological conditions, combined with the impact of human activity and the physical characteristics of the river's structure. Based on the values of CTSI, the lakes will be classified according to Table 6.

Table 6 *Carlson's trophic state index values and classification of lakes [5]*

TSI values	Trophic Status	Attributes
<30	Oligotrophic	Clear water, oxygen throughout the year in the hypolimnion
30-40	Oligotrophic	A lake will still exhibit oligotrophy, but some shallower lakes will become anoxic during the summer
40-50	Mesotrophic	Water moderately clear, but increasing probability of anoxia during the summer
50-60	Eutrophic	Lower boundary of classical eutrophic: Decreased transparency, warm-water fisheries only
60-70	Eutrophic	Dominance of blue-green algae, algal scum probable, extensive macrophyte problems
70-80	Eutrophic	Heavy algal blooms possible throughout the summer, often hypereutrophic
>80	Eutrophic	Algal scum, summer fish kills, few macrophytes

2.5 Data Analysis

The application of Bioindicator Sampling, the Water Quality Index (WQI), and the Trophic Status Index (TSI) was included in the data analysis phase. In the bioindicator technique, the presence and diversity of macroinvertebrate and algal species were investigated. On the other hand, the values of WQI and TSI from past research will be used to assess the comparability of water quality status. These species are used as markers of the health of the ecosystem and the quality of the water.

A correlation exists between the parameters that control water quality and the diversity and abundance of macroinvertebrates. High diversity and the presence of species sensitive to pollution are indicators of good water quality. On the other hand, low diversity and the predominance of species that are tolerant of pollution are indicators of poor water quality. To determine the overall health of the lake's ecology, the structure of the macroinvertebrate community is taken into consideration.

3. Results and Discussion

3.1 Bioindicator Method Parameter

Following the collection process through site analysis and findings, the data was categories according to score referred to Biological Monitoring Working Party Score (BMWP) to assess the water quality of the artificial lake. The findings will be tabulated according to species and score, as shown in Table 7.

This study focuses on two sampling stations along the stream leading to Tasik Kemajuan, specifically at RMC (Station 1) and Dewan Sultan Ibrahim (Station 2), to evaluate the ecological condition of the water using macroinvertebrate bioindicators. Macroinvertebrates were collected, identified, and their respective scores and families recorded at each station. The analysis reveals similarities in the composition and abundance of macroinvertebrates between the stations, likely due to the shared flow of water toward the same location. Station 1 recorded four individuals representing four families, while Station 2 recorded seven individuals from seven families, indicating slight differences in habitat suitability and water quality along the stream gradient. These variations suggest localized environmental factors influencing the diversity and abundance of macroinvertebrates. Despite these differences, the overall assessment classifies the water quality as Class II, with a score range of 5.1–7.5, which corresponds to water that is relatively clean to clean. This classification highlights the ecological health of the stream and its potential for supporting aquatic biodiversity.

Table 7 *Macroinvertebrates founded in each sampling location*

Location	Macroinvertebrates	BMWP Score	Number of Families
Station 1 (RMC)	Pagoda snails	6	1
	Spring snails	5	1
	Mystery snails	3	1
	Very short spiky tails	6	1
	Total	20	4
	ASPT Index	20/4 = 5	
Station 2 (Dewan Sultan Ibrahim)	Common damselfly	6	1
	Common saucer bug	5	1
	Water cricket	5	1
	Water mite	5	1
	Long mouthed saucer bug	10	1
	Phantom midge larva	5	1
	Water beetles	5	1
	Total	41	7
	ASPT Index	$41/7 = 5.9 \approx 6$	

3.2 Comparative between WQI and Bioindicator

Table 8 presents the water quality index (WQI) readings for *Tasik Kemajuan* based on the standard formula, as derived from past research conducted in 2023. The WQI is essential for classifying water quality in accordance with the National Water Quality Standards (NWQS). Lower WQI scores indicate higher pollution levels, while higher scores signify better water quality. In this study, WQI results indicate that all stations contributing to Tasik Kemajuan fall under Class III, with average scores of 72.87, 73.95, and 73.56, reflecting slightly polluted conditions that require extensive treatment for safe use. Consistent WQI values across stations suggest uniform water characteristics influenced by similar flow dynamics. Flow rate plays a critical role in water quality, as slower flows reduce pollutant dilution, while faster flows improve mixing and pollutant dispersion. Factors such as upstream topography and land use have a significant impact on flow and ecological health. The classification of water in Class III highlights the need for effective treatment processes and continuous monitoring to address emerging pollution trends. Detailed hydrological studies and analysis of upstream factors are necessary to improve water quality management.

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Table 8 *Water quality index of Tasik Kemajuan*

Sampling Point	Weeks										Average
	1	2	3	4	5	6	7	8	9	10	
1	75.14	70.51	75.41	67.63	70.86	72.32	74.69	73.97	71.84	76.35	72.87
2	75.23	70.89	76.43	70.87	74.08	73.79	75.56	75.56	71.84	75.26	73.95
3	74.46	70.35	74.83	68.04	74.42	74.55	73.60	75.25	73.55	76.55	73.56

Bioindicator analysis based on macroinvertebrate populations provides additional ecological insights. At Station 1 (RMC), a BMWP score of 20 and an ASPT index of 5 place the water in Class B, indicating relatively good quality and positive ecological conditions. Station 2 (near Dewan Sultan Ibrahim) recorded a higher macroinvertebrate diversity with a BMWP score of 41 and an ASPT index of 6, also categorized as Class B. These results suggest that the stream's water quality ranges from rather clean to clean, reflecting stable ecological conditions. Similar ASPT values at both stations indicate comparable macroinvertebrate diversity, influenced by natural factors such as flow dynamics and substrate composition. Variations in these conditions could affect macroinvertebrate populations and water quality assessments.

A comparison of WQI and bioindicator metrics reveals complementary insights. WQI quantitatively assesses physical and chemical parameters, while bioindicators qualitatively reflect the health and diversity of aquatic organisms. Therefore, these methods provide a comprehensive understanding of water quality, with WQI emphasizing the need for consistent monitoring and bioindicators highlighting the ecological health of the stream. Integrating both approaches supports targeted strategies for improving the water quality of *Tasik Kemajuan*, ensuring sustainable management and ecological balance.

3.3 Comparative Between TSI and Bioindicator

Table 9 presents the Carlson's Trophic State Index (TSI) readings for Tasik Kemajuan at UTHM, derived using the parameters of total phosphorus, chlorophyll-a, and secchi disk transparency. The results classify Tasik Kemajuan as eutrophic, indicating high nutrient levels that promote excessive algae growth and cause oxygen depletion in deeper layers. CTSI scores (76.36 to 79.51) confirm consistent eutrophic conditions across sampling weeks. Elevated Chlorophyll-a levels (71.51 to 109.48) and reduced water clarity (Secchi Disk readings) further highlight significant algal biomass. Total Phosphorus levels remain consistently within the eutrophic range, emphasizing nutrient enrichment. The uniform TSI scores reflect stable but poor water quality, dominated by nutrient-induced eutrophication, which stresses the need for effective management strategies to reduce nutrient inflows and control algal blooms. Recommended interventions include upstream catchment management and reducing agricultural runoff to limit phosphorus loading.

The bioindicator method complements TSI analysis by providing biological insights into ecological health. Macroinvertebrate assessments reveal moderate diversity, with Station A exhibiting a BMWP score of 30 and an ASPT index of 4.5, indicating moderate levels of pollution. Meanwhile, Station B records higher values, suggesting slightly better conditions.

The correlation between TSI and bioindicator metrics shows that eutrophic conditions favour pollution-tolerant species while reducing sensitive taxa. This integration of TSI and bioindicator methods offers a comprehensive understanding of water quality dynamics. The findings emphasize the need for ongoing monitoring and targeted management to address eutrophication and its ecological impacts on Tasik Kemajuan. Combining chemical and biological assessments improves evaluation reliability and supports sustainable water quality management and ecological restoration.

Table 9 *Carlson's trophic state index of Tasik Kemajuan*

Week	Parameter	Results	CTSI	Trophicstatus	Condition
1	TSI of Total Phosphorus TSI of Chlorophyll-a TSI of Secchi Disk	111.46 71.51 55.56	79.51	Eutrophic	High levels of algae growth and depletion of oxygen in the lower layers of the water
2	TSI of Total Phosphorus TSI of Chlorophyll-a TSI of Secchi Disk	68.75 106.39 56.65	77.26	Eutrophic	High levels of algae growth and depletion of oxygen in the lower layers of the water
3	TSI of Total Phosphorus TSI of Chlorophyll-a TSI of Secchi Disk	66.11 108.64 56.40	77.05	Eutrophic	High levels of algae growth and depletion of oxygen in the lower layers of the water
4	TSI of Total Phosphorus TSI of Chlorophyll-a TSI of Secchi Disk	67.14 105.55 56.38	76.36	Eutrophic	High levels of algae growth and depletion of oxygen in the lower layers of the water
5	TSI of Total Phosphorus TSI of Chlorophyll-a TSI of Secchi Disk	69.11 109.48 55.93	78.18	Eutrophic	High levels of algae growth and depletion of oxygen in the lower layers of the water

3.4 Integrate Analysis

The comparison of bioindicator, Water Quality Index (WQI), and Trophic State Index (TSI) results for *Tasik Kemajuan* provides complementary insights into the lake's water quality and ecological health. The bioindicator analysis, based on macroinvertebrates, classifies the water as Class II (relatively clean), indicating moderate biodiversity and favourable ecological conditions at Stations 1 and 2. The WQI analysis, averaging 72.87 to 73.95, classifies the water as Class III (slightly polluted), emphasizing the need for extensive water treatment before use and the importance of hydrological factors in pollutant dispersion. The TSI results classify the lake as eutrophic, withCTSI scores of 76.36 to 79.51, indicating nutrient enrichment, high algal growth, and oxygen depletion in deeperlayers. Each method offers unique insights: bioindicators reflect aquatic biodiversity, WQI evaluates chemical water quality, and TSI assesses nutrient-driven productivity. Together, these approaches provide a comprehensive understanding regarding the water quality of *Tasik Kemajuan* and emphasize the need for integrated management strategies to ensure ecological balance and water sustainability.

4. Conclusion

This study conducted a comprehensive assessment of the water quality in Tasik Kemajuan at Universiti Tun Hussein Onn Malaysia (UTHM) by integrating bioindicator, Water Quality Index (WQI) and the Trophic Status. Index (TSI). The accomplishment of the study objectives, which determined the water quality status within the artificial lake of UTHM using bioindicator approaches, was compared with the water quality index and trophic status index from past research. Additionally, another objective has been achieved, as this study successfully analyzed the water quality status from three different aspects. The findings indicate that the lake is predominantly eutrophic, characterizedby elevated nutrient concentrations that promote algal blooms and contribute to oxygen depletion in deeper water layers. This condition poses significant ecological challenges, affecting aquatic life and the overall health ofthe lake. The use of bioindicators, specifically macroinvertebrates, provided valuable insights into the biological impacts of these nutrient-rich conditions.

These organisms, known for their sensitivity to environmental changes, reflected the effects of pollution and nutrient loading on the lake's ecosystem. As for this study, the result of bioindicator sampling categorizes the lake as having rather clean to clean water, corresponding to Class II. Together, the chemical and biological assessments revealed a consistent pattern of moderate to poor water quality, underscoring the need for targeted management strategies. This study emphasizes the importance of integrating multiple evaluation methods to gain a comprehensive understanding of water quality dynamics, particularly in artificial lakes where natural processes and anthropogenic influences intersect.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors are responsible for the study conception, research design, data collection, data analysis, result interpretation and manuscript drafting.

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