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Assessment of River Water Quality Using Physicochemical Parameters and Water Quality Index (WQI): A Case Study of Sungai Besar, Tunjang, Kedah

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Abstract: River water quality assessment is essential for sustaining aquatic ecosystems and supporting sustainable water use, particularly in irrigation rivers influenced by mixed land use activities. This study evaluated the water quality status of Sungai Besar, Tunjang, through the Terusan Utara in Jitra, Kedah, using physicochemical parameters and the Malaysian Water Quality Index framework. Water samples were collected from three sampling stations over three months, from June to August, using the grab sampling method. Parameters analysed included pH, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, ammoniacal nitrogen, and total suspended solids. Measured values were compared with the National Water Quality Standards of Malaysia and integrated into Water Quality Index calculations. The results showed clear variation in water quality along the river. Stations 1 and 3 exhibited good water quality, with most parameters classified within Class I and Class II, and Water Quality Index values ranging from 88.81 to 96.47. In contrast, Station 2 showed significant degradation, with biochemical oxygen demand and chemical oxygen demand values reaching 77.5 mg/L and 295 mg/L, respectively, resulting in polluted to slightly polluted Water Quality Index classifications ranging from 44.54 to 71.57. Elevated ammoniacal nitrogen and episodic increases in suspended solids further indicated substantial organic and chemical pollution. Overall, this study provides updated baseline data for irrigation rivers in northern Kedah and supports site-specific river management and sustainable agricultural water use.

Keywords: *National Water Quality Index, River Pollution, River Water Quality, Water Quality Assessment, Water Quality Index*

1.0 Introduction

Water quality plays an essential role in sustaining aquatic ecosystems and safeguarding human well-being, particularly in regions that rely on surface water for agriculture, domestic use, and economic activities. Rivers represent a major source of freshwater, yet their quality has been increasingly compromised by intensified human activities. Agricultural runoff, industrial discharge, and domestic wastewater have collectively contributed to the deterioration of river water quality, thereby posing serious risks to ecological stability and public health.

The water quality of a specific area or source can be assessed using physical, chemical, and biological parameters. When the values of these parameters exceed established guideline limits, they may pose significant risks to human health (World Health Organization, 2012). For this reason, regular and systematic water quality assessment is a critical component of effective water resource management and environmental protection.

Agricultural activities are widely recognised as a major contributor to river pollution, mainly through the release of nutrients such as nitrogen and phosphorus into water bodies. Excessive nutrient inputs can disrupt aquatic ecosystems and promote the growth of harmful algal blooms, which further degrade water quality. Evidence from the Beichuan River in China has shown that nutrient pollution originating from agricultural fertilizers resulted in severe river contamination, clearly demonstrating the strong influence of agricultural runoff on river systems (Xiao et al., 2020).

Industrial discharge represents another significant source of river pollution by introducing a wide range of contaminants into aquatic environments. These pollutants often include heavy metals, hydrocarbons and other toxic chemicals. Industrial effluents may also contain high concentrations of ammonia, phosphates and related substances, which can cause serious harm to aquatic organisms and disrupt ecosystem balance. Studies conducted on the Damanganga River have identified industrial discharge as a major contributor to water quality degradation, where pollutant inputs significantly intensified contamination levels (Godhaniya et al., 2024). Similar conditions have been reported for the Shatt Al Arab River in Iraq, where untreated industrial waste combined with domestic sewage has resulted in poor water quality, particularly in areas with high industrial activity (Hamdan et al., 2018).

In Malaysia, river pollution has become a persistent environmental concern. Reports indicate that many rivers flowing through urban and semi urban areas are classified as polluted, largely due to inadequate control of industrial discharge and ineffective waste management practices. In addition to conventional pollutants, emerging contaminants have also attracted increasing attention. Hafiz et al. (2024) reported the presence of microplastics in the Melaka River, with an average concentration of 569 particles per litre. These microplastics were primarily composed of polyamide and polyethylene terephthalate, which are known to persist in aquatic environments and may pose harmful effects on aquatic organisms and potential risks to human health. These findings highlight the increasing complexity of river pollution in Malaysia and reinforce the need for comprehensive water quality assessment.

The WQI is one of the most widely applied tools for evaluating river water quality because it integrates several key physicochemical parameters into a single numerical value. Parameters such as dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, ammoniacal nitrogen, suspended solids and pH are commonly used to classify river water quality according to national standards. The application of the WQI supports informed decision-making in river management, pollution control and environmental policy development.

Sungai Besar, Tunjang, which flows through the Terusan Utara in Jitra, Kedah, is an important river system that supplies irrigation water from Kedah to Perlis. The river flows through areas characterized by mixed land use, including agricultural and industrial activities, which may exert cumulative pressure on water quality. Preliminary observations and discussions with relevant authorities suggest that this river may be exposed to pollution risks, highlighting the need for a detailed scientific assessment.

Although numerous studies have investigated the impacts of agricultural runoff, industrial discharge and emerging contaminants on river water quality, most existing research has focused on large or highly urbanized river systems. Comparatively limited attention has been given to medium scale irrigation rivers that support agricultural activities while simultaneously receiving industrial and domestic inputs. In Malaysia, published studies using the WQI are unevenly distributed across regions, with a lack of recent and site specific data for rivers in northern Kedah. Furthermore, few studies have systematically compared physicochemical water quality parameters with the National Water Quality Standards (NWQS) to evaluate river suitability for agricultural use. This absence of updated and location specific evidence constrains effective river management and conservation planning.

Therefore, this study evaluates the water quality status of Sungai Besar, Tunjang through systematic analysis of selected physicochemical parameters and classification using the Malaysian WQI framework. By benchmarking observed parameter values against the NWQS, this research provides updated baseline data to support river management strategies, assist regulatory authorities and promote sustainable use of freshwater resources in agricultural regions.

2.0 Literature Reviews

Rivers serve as vital components of aquatic ecosystems and play an essential role in supporting human communities by providing water for domestic use, agriculture, and economic activities. However, rapid population growth and increasing industrialisation have intensified pressure on river systems, leading to widespread pollution. Rivers are often used as disposal pathways for domestic waste, industrial effluents, and agricultural runoff, which accelerates the degradation of water quality and disrupts ecological balance. A bibliometric analysis by Imelda et al. (2025) highlighted that river pollution research consistently links anthropogenic activities with declining ecosystem health, indicating that human-induced pressures remain the dominant driver of water quality deterioration in freshwater systems.

The presence of human settlements along riverbanks further accelerates water pollution. Untreated domestic waste, food residues, and sewage from residential areas are frequently discharged directly into rivers, increasing organic loading and microbial contamination. In addition, small-scale industries and small and medium enterprises contribute pollutants such as oil residues and solid waste when waste disposal practices fail to comply with established treatment standards. A study conducted in rural areas of Johor demonstrated that these combined activities significantly degraded river water quality and adversely affected surrounding ecosystems and community well-being, showing that river pollution is not limited to highly urbanised environments (Haryati et al., 2018).

Industrial activities represent a major source of river pollution through the release of hazardous chemicals and untreated effluents. Industrial discharge often contains elevated concentrations of ammonia, phosphates and synthetic compounds that are harmful to aquatic organisms. The vulnerability of river systems to industrial pollution has been clearly illustrated through documented pollution incidents. For example, a chemical leak from an acrylic processing facility in Selangor resulted in odour pollution that forced the shutdown of the Sungai Selangor water treatment plant, demonstrating the direct impact of industrial contamination on public water supply systems (Amirul, 2024). Such incidents highlight the need for stricter industrial waste management and continuous monitoring of river systems.

Beyond industrial discharge, infrastructure development can significantly alter natural hydrological processes and contribute to water quality degradation. Research on Tasik Chini revealed that dam construction disrupted natural water flow, reduced circulation and promoted bacterial growth within the lake. These changes were further exacerbated by soil erosion along lake banks, particularly during prolonged rainfall events, which increased sediment loads and reduced water clarity. The resulting decline in water quality posed serious threats to aquatic ecosystems and the livelihoods of indigenous communities dependent on the lake, illustrating how poorly managed development can have long term environmental consequences (Ida & Md. Jamin, 2021).

Land use activities within river catchments also play a critical role in influencing water quality. Studies conducted on Sungai Liwagu in Sabah showed that although the overall WQI classification indicated good water quality, elevated chemical oxygen demand values were recorded at specific locations. These elevated values were closely linked to land use activities such as tourism, agriculture, livestock farming, and residential development. This finding suggests that general river classifications may conceal localised pollution hotspots and highlights the importance of site-specific assessment (Hashim et al., 2020).

Seasonal variability further complicates water quality evaluation. An assessment of the Citarum River in Indonesia demonstrated that WQI classifications varied significantly between wet and dry seasons. These findings indicate that short-term or single-season assessments may not adequately represent long-term water quality conditions. As a result, water management decisions based on limited temporal data may be ineffective or inaccurate, emphasising the importance of long term monitoring programs (Marselina et al., 2022).

The WQI is widely used as an assessment tool because it simplifies complex water quality data into a single numerical value that is easily interpreted by decision makers. A comprehensive review by Chidiac et al. (2023) noted that WQI methods are effective for identifying pollution trends and supporting environmental management policies. However, several studies have highlighted limitations associated with reliance on physicochemical parameters alone. Research on the Sarawak River found that while the Malaysian WQI classified the river as having relatively good water quality, microbiological indicators revealed a higher level of pollution risk. This discrepancy suggests that assessments based solely on physicochemical parameters may underestimate potential public health risks (Sim & Tai, 2018).

To address these limitations, researchers have increasingly advocated for integrated assessment approaches. A study conducted at Sungai Durian Perangin demonstrated that combining physicochemical parameters with biological indicators such as benthic macroinvertebrates provided a more comprehensive understanding of river ecosystem health. This integrated approach captured ecological responses that were not reflected by physicochemical data alone (Farah Safiah et al., 2020). Similar conclusions were reported in a study conducted in Vietnam, where the combined use of the WQI and Pollution Index improved the accuracy of river pollution classification and better reflected actual environmental conditions (Son et al., 2020).

Advances in monitoring technology have further enhanced the ability to assess river water quality at broader spatial and temporal scales. The integration of remote sensing data, artificial intelligence, and smart monitoring technologies has enabled more efficient detection of pollution patterns at reduced costs. Najafzadeh and Basirian (2023) demonstrated that combining remote sensing with intelligent modelling techniques allowed for improved identification of polluted areas and spatial variability in water quality. Despite these advancements, field based and site specific studies remain essential, particularly in regions where local land use activities and hydrological conditions strongly influence water quality outcomes.

The reviewed studies collectively demonstrate that river water quality is strongly influenced by a combination of agricultural activities, industrial discharge, land use patterns and hydrological modifications. While the WQI remains a widely accepted tool for simplifying complex water quality data and supporting management decisions, existing research also highlights its limitations when applied without site specific analysis and continuous monitoring. Evidence from both Malaysian and international studies indicates that medium scale rivers serving agricultural functions are particularly vulnerable to pollution from mixed land use activities, yet these river systems remain underrepresented in recent water quality assessments. In the context of Sungai Besar, Tunjang, which functions as a critical irrigation channel while flowing through agricultural and industrial zones, there is a clear need for an updated and systematic evaluation of water quality conditions. Therefore, applying the Malaysian WQI to Sungai Besar, Tunjang provides an essential opportunity to generate site specific data, assess compliance with national standards and support more effective river management and conservation strategies in northern Kedah.

3.0 Methodology

3.1 Research Design

This study adopted a quantitative research design based on the collection and analysis of numerical data to evaluate river water quality. Primary data were obtained through fieldwork involving direct water sampling at Sungai Besar, Tunjang, which flows through the Terusan Utara in Jitra, Kedah. Water samples were collected directly from the river to ensure that the data reflected actual environmental conditions. Three sampling stations were identified along Sungai Besar, Tunjang based on river flow characteristics, surrounding land use and potential exposure to anthropogenic activities such as agriculture, industrial operations and residential settlements. Each sampling station was analysed using six key water quality parameters, namely pH, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total suspended solids and ammoniacal nitrogen. These parameters were selected because they are commonly used to assess river water quality and form the basis of the Malaysian WQI.

Time variation was considered in the data collection process to capture changes in river conditions over the study period. Water sampling was conducted over a period of three months, with samples collected once per month. This approach allowed for a systematic assessment of water quality and reduced the influence of short term fluctuations.

3.2 Study Area

The study was conducted at Sungai Besar, Tunjang, which flows through the Terusan Utara in the Tunjang area of Jitra, Kedah. This river functions as a major water channel that passes through agricultural land and residential areas and plays an important role in the irrigation system for paddy fields managed by the Muda Agricultural Development Authority (MADA). Three water sampling locations were selected based on preliminary field observations. The selection of these locations considered their exposure to surrounding agricultural and industrial activities that could influence river water quality. As shown in Figure 1, the sampling stations were distributed along a river stretch of approximately 15 kilometres, from Station 1 to Station 3. Stations 1 and 3 were located near residential areas, while Station 2 was situated close to a rice processing facility. This distribution enabled a comparative evaluation of water quality conditions under different levels of human activity along the river.

Figure 1: Sample location

3.3 Water Sampling Method

Water sampling was conducted at the three identified sampling stations along Sungai Besar through the Terusan Utara in the Tunjang area of Jitra, Kedah. These stations were selected to represent different river conditions within the same river system and were located at intervals of approximately 5 kilometres from one station to the next. Sampling stations were chosen based on accessibility, physical river conditions and the potential influence of external inputs from human activities such as agriculture, industrial operations and nearby residential settlements. Water samples were collected during three sampling sessions conducted in June, July and August, with one sampling session carried out each month during this period. The grab sampling method was used for water collection, where water was collected directly into sample containers at a specific point in time. This method is suitable for assessing river water quality at the time of sampling. All samples were collected in the morning between 8.00 a.m. and 11.00 a.m. to maintain consistency in environmental conditions such as temperature and human activity that could affect water quality readings. An ex-situ approach was applied for laboratory analysis. Water samples were collected using one litre plastic bottles that were clean and free from contamination. For laboratory transport and analysis, samples intended for biochemical oxygen demand

and total suspended solids measurements were stored in a cooled condition at a temperature of 4°C plus or minus 2°C to preserve sample stability until analysis.

3.4 Laboratory Analysis

Laboratory tests were conducted to obtain accurate data on water quality conditions at the sampling locations. Analysis involved six main parameters, namely pH, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total suspended solids and ammoniacal nitrogen. These parameters were used to evaluate overall water pollution levels and served as the basis for WQI calculation in the study area. All laboratory analyses were performed in accordance with the Standard Methods for the Examination of Water and Wastewater developed by the American Public Health Association (APHA). The analytical procedures followed standard protocols to ensure accuracy, reliability and repeatability of results. Specific analytical methods for each parameter are summarised in Table 1. All tests were carried out carefully following prescribed procedures to ensure compliance with international laboratory standards.

Table 1: Standard method of parameter

Parameter	Standard Method
Chemical Oxygen Demand (COD)	APHA 5220B 2005
Dissolved Oxygen (DO)	APHA 4500-OG 2017
pH	APHA 4500-H^+B 2005
Biochemical Oxygen Demand (BOD)	APHA 5210B 2017
Total Suspended Solids (TSS)	APHA 2540D 2005
Ammoniacal Nitrogen (NH_3-N)	APHA 4500-NH_3 B & C 2005

3.5 Data Analysis

Water quality data obtained from laboratory analysis were used to calculate the WQI for each sampling station. The assessment followed the Malaysian WQI framework as recommended by the Department of Environment Malaysia. Measured values of each water quality parameter were first transformed into corresponding sub-index values, namely the sub-index of dissolved oxygen (Eq. 1), biochemical oxygen demand (Eq. 2), chemical oxygen demand (Eq. 3), ammoniacal nitrogen (Eq. 4), total suspended solids (Eq. 5) and pH (Eq. 6) (Department of Environment Malaysia, 2017).

$$SI_{DO} = \begin{cases} 0 & for\ DO < 8 \\ 100 & for\ DO < 92 \\ -0.395 + 0.030DO^2 - 0.00020DO^3 & for\ 8 < DO < 8 \end{cases} \quad (1)$$

Subindex DO (% saturation)

$$SI_{BOD} = \begin{cases} 100.4 - 4.23BOD & for\ BOD < 5 \\ 108^{e-0.055BOD} - 0.1BOD & for\ BOD > 5 \end{cases} \quad (2)$$

$$SI_{COD} = \begin{cases} -1.33COD + 99.1 & for\ COD < 20 \\ 103^{e-0.0157COD} - 0.04COD & for\ COD > 20 \end{cases} \quad (3)$$

$$SI_{\mathrm{NH3-N}} = \begin{cases} 100.5 - 105\mathrm{N}H_3 - \mathrm{N} & for\ \mathrm{N}H_3 - \mathrm{N} < 0.3 \\ 94^{e-0.573\mathrm{NH3-N}} - 5|\mathrm{N}H_3 - 2| & for\ 0.3 < \mathrm{N}H_3 - \mathrm{N} < 4 \\ 0 & for\ \mathrm{N}H_3 - \mathrm{N} > 4 \end{cases} \quad (4)$$

$$SI_{SS} = \begin{cases} 97.5e^{-0.00676SS} + 0.05SS & for\ SS < 100 \\ 71^{e-0.0016SS} - 0.015SS & for\ 100 < SS < 1000 \\ 0 & for\ SS > 1000 \end{cases} \quad (5)$$

$$SI_{pH} = \begin{cases} 17.2 - 17.2pH + 5.02pH^2 & for\ pH < 5.5 \\ -242 + 95.5pH - 6.67pH^2 & for\ 5.5 < pH < 7 \\ -181 + 82.4pH - 6.05pH^2 & for\ 7 < pH < 8.75 \\ 5.36 - 77.0pH + 2.76pH^2 & for\ pH > 8.75 \end{cases} \quad (6)$$

These sub-index values represent the relative contribution of individual parameters to overall river water quality. The sub-index values were calculated using established empirical equations based on parameter-specific concentration ranges. Dissolved oxygen was expressed as percentage saturation and converted into its sub-index value using the standard polynomial relationship. Separate equations were applied for biochemical oxygen demand and chemical oxygen demand depending on whether the measured concentrations were below or above the defined threshold values. Similarly, ammoniacal nitrogen, total suspended solids, and pH were converted into their respective sub-index values using predefined mathematical functions. This approach ensured consistency with national water quality assessment guidelines. The WQI was then computed by combining all sub-index values using a weighted aggregation formula (Eq. 7) (Department of Environment Malaysia, 2017). The weighting factors reflect the relative importance of each parameter in determining overall water quality. The WQI was calculated using the following expression:

$$WQI = (0.22\ x\ SIDO) + (0.19\ x\ SIBOD) + (0.16\ x\ SICOD) + (0.15\ x\ SINH_3 - N) + (0.16\ x\ SISS) + (0.12 + SIpH) \quad (7)$$

where:

WQI	=	water quality index
SI_{DO}	=	sub-index of DO
SI_{BOD}	=	sub-index of BOD
SI_{COD}	=	sub-index of COD
SI_{NH3-N}	=	sub-index of NH_3-N
SI_{SS}	=	sub-index of TSS
SI_{pH}	=	sub-index of pH

The calculated WQI values were interpreted using the standard Malaysian WQI classification system.

Table 2: WQI classification and water quality status

WQI Range	Water Quality Status	Class
0-59	Polluted	IV-V
60-79	Slightly Polluted	III
80-100	Clean	I-II

(Department of Environment Malaysia, 2017)

4.0 Findings

4.1 Water Quality Parameters and NWQS Classification

The water quality assessment of Sungai Besar, Tunjang, through the Terusan Utara was conducted at three sampling stations over three sampling periods. The results showed clear differences in water quality between locations and over time, reflecting the influence of surrounding land use and human activities. Overall, distinct differences were observed among the stations, with Station 2 consistently exhibiting poorer water quality compared to Stations 1 and 3. Dissolved oxygen concentrations across the study area ranged from 5 to 8 mg/L. Stations 1 and 3 consistently recorded higher dissolved oxygen levels, with most values classified as Class I, indicating very good water quality. Station 2 recorded slightly lower dissolved oxygen concentrations, ranging from 5 to 6 mg/L, corresponding to Class II. Despite these variations, dissolved oxygen levels at all stations remained within acceptable limits for supporting aquatic life based on the NWQS of Malaysia. Biochemical oxygen demand exhibited clear differences between stations. Stations 1 and 3 consistently recorded low BOD values of 2 mg/L throughout the study period, corresponding to Class II and indicating low organic pollution. In contrast, Station 2 recorded extremely high BOD concentrations ranging from 20.4 to 77.5 mg/L, which were classified as Class V. These results indicate severe organic pollution at Station 2 and suggest the presence of strong localised pollution sources. Chemical oxygen demand followed a similar pattern between stations. Stations 1 and 3 recorded low COD values ranging from 0.7 to 5.1 mg/L, consistently classified as Class I, reflecting minimal chemical contamination. Conversely, Station 2 exhibited substantially elevated COD concentrations, with values reaching 295 mg/L, corresponding to Class V, while other measurements at this station were classified as Class III. These findings indicate significant oxidisable pollutant inputs at Station 2.

Ammoniacal nitrogen concentrations varied notably among the sampling stations. Stations 1 and 3 predominantly recorded NH_3–N values within Classes I and II, indicating low ammonia levels. Station 2 recorded elevated NH_3–N concentrations ranging from 0.86 to 0.97 mg/L, corresponding to Classes III to V. These elevated levels reflect considerable nitrogen loading at this station. Total suspended solids concentrations were generally low to moderate across the study area. Stations 1 and 3 recorded TSS values mainly within Classes I and II, indicating good water clarity. Station 2 recorded a higher TSS concentration of 51 mg/L during one sampling event, classified as Class III, while subsequent measurements were within Class I. This variation suggests temporary increases in suspended solids at this location. The pH values ranged from 5.0 to 7.2, indicating slightly acidic to near-neutral conditions. Stations 1 and 3 generally exhibited pH values within Classes I and II, reflecting stable chemical conditions. Station 2 recorded lower pH values during certain sampling periods, falling within Class III. No extreme pH conditions were observed during the study period. In summary, Sungai Besar, Tunjang demonstrated good water quality at Stations 1 and 3, with most parameters classified within Classes I and II under the NWQS of Malaysia. In contrast, Station 2 consistently exhibited degraded water quality, particularly for organic and chemical pollution indicators such as BOD, COD, and ammoniacal nitrogen, highlighting clear differences in water quality along the river.

Table 3: Water quality parameters and NWQS classes in Sungai Besar, Tunjang through Terusan Utara, Jitra, Kedah

Water Quality Parameter	Date	Water Sampling					
		Station 1		Station 2		Station 3	
		Concentration	Class	Concentration	Class	Concentration	Class
DO (mg/L)	6/6/25	7	I	6	II	8	I
	2/7/25	7	I	5	II	7	I
	13/8/25	6	II	6	II	7	I
BOD (mg/L)	6/6/25	2	II	77.5	V	2	II
	2/7/25	2	II	20.4	V	2	II
	13/8/25	2	II	27.2	V	2	II
COD (mg/L)	6/6/25	4.7	I	295	V	5.1	I
	2/7/25	0.7	I	31.7	III	0.7	I
	13/8/25	2.0	I	32.2	III	2.2	I
NH_3-N (mg/L)	6/6/25	0.12	II	0.86	V	0.2	II
	2/7/25	0.01	I	0.97	III	0.05	I
	13/8/25	0.19	II	0.01	IV	0.14	II
TSS (mg/L)	6/6/25	29	II	51	III	31	II
	2/7/25	16	I	3	I	20	I
	13/8/25	22	I	16	I	15	I

pH	6/6/25	7.2	I	5	III	5.8	III
	2/7/25	6.2	II	5.9	III	6.0	II
	13/8/25	6.9	I	6.3	II	6.8	I

4.2 Water Quality Index and Sub-Index Analysis

Assessment of the WQI along Sungai Besar, Tunjang indicated uneven water quality conditions across the monitored stations, with variations linked to differences in environmental pressure and human activities. At Station 1, WQI values ranged from 89.92 to 96.47, indicating consistently clean water conditions throughout the study period. The river at this station was classified as Class I to Class II. High sub-index values for dissolved oxygen, biochemical oxygen demand, chemical oxygen demand and pH were consistently recorded, reflecting stable physicochemical conditions and low levels of organic and chemical pollution. Minor fluctuations in ammoniacal nitrogen and suspended solids did not significantly affect the overall water quality status, which remained within the clean category during all sampling events. In contrast, Station 2 exhibited considerable variation in WQI values, ranging from 44.54 to 71.57. The river water quality at this station deteriorated markedly during the first sampling period, where a WQI value of 44.54 classified the river as Class IV and polluted. This degradation was primarily driven by extremely low sub-index values for biochemical oxygen demand and chemical oxygen demand, indicating severe organic and chemical pollution. During subsequent sampling periods, WQI values improved to 63.70 and 71.57, corresponding to Class III and slightly polluted conditions.

Despite this improvement, sub-index values for biochemical oxygen demand and ammoniacal nitrogen remained relatively low, suggesting persistent pollution pressure at this location. Station 3 demonstrated generally good water quality conditions, with WQI values ranging from 88.81 to 92.84. The river at this station was classified as Class I to Class II and consistently categorised as clean. Sub-index values for dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, and pH remained high throughout the study period. Although slight variations were observed in ammoniacal nitrogen and suspended solids sub-indices, these changes did not substantially affect the overall water quality classification. Overall, the WQI results indicate that Sungai Besar, Tunjang exhibits good water quality at Stations 1 and 3, with stable and clean conditions observed throughout the monitoring period. In contrast, Station 2 showed degraded water quality, particularly during the initial sampling event, with gradual improvement over time. These findings highlight clear differences in water quality conditions along the river and demonstrate the influence of localised pollution sources on the overall river health.

Table 4: WQI, Sub-Index Values, and classification at Sungai Besar, Tunjang through Terusan Utara, Jitra, Kedah

Station	Date	Sub-Index						WQI	Class	Water Quality Status
		SI_{DO}	SI_{BOD}	SI_{COD}	$SI_{\mathrm{NH3-N}}$	SI_{SS}	SI_{pH}			
1	6/6/25	95.309	91.94	92.849	87.9	81.595	98.648	91.39	II	Clean
	2/7/25	96.965	91.94	98.169	99.45	99.197	93.705	96.47	I	Clean
	13/8/25	88.127	91.94	96.44	80.55	85.145	99.391	89.92	II	Clean
2	6/6/25	84.205	0	0	51.734	71.58	56.7	44.54	IV	Polluted
	2/7/25	64.727	33.168	61.356	48.806	95.69	89.267	63.70	III	Slightly Polluted
	13/8/25	78.757	21.472	60.821	99.45	88.258	94.918	71.57	III	Slightly Polluted
3	6/6/25	96.53	91.94	92.317	79.5	80.62	87.52	88.81	II	Clean
	2/7/25	93.91	91.94	98.169	95.25	86.215	90.88	92.84	I	Clean
	13/8/25	92.253	91.94	96.174	85.8	88.848	98.979	92.06	II	Clean

5.0 Discussion and Conclusion

5.1 Discussion

The results of this study demonstrate marked differences in water quality conditions along Sungai Besar, Tunjang through the Terusan Utara, as reflected by variations in physicochemical parameters, NWQS classifications and WQI values across the three sampling stations. These differences highlight the influence of localised human activities on river water quality within a relatively short river stretch. Stations 1 and 3 consistently exhibited good water quality throughout the study period. Dissolved oxygen concentrations at Station 1 ranged from 6 to 7 mg/L, while Station 3 recorded values between 7 and 8 mg/L, corresponding to Class I and Class II conditions. These values indicate favourable oxygen conditions for aquatic organisms. Biochemical oxygen demand values at both stations remained constant at 2 mg/L across all sampling periods and were classified as Class II, indicating low levels of organic pollution. Similarly, chemical oxygen demand concentrations remained low, ranging from 0.7 to 4.7 mg/L at Station 1 and from 0.7 to 5.1 mg/L at Station 3, all within Class I. Ammoniacal nitrogen concentrations at these stations were generally low, between 0.01 and 0.19 mg/L, while total suspended solids values were mostly below 31 mg/L. The pH values ranged from 6.0 to 7.2, reflecting stable chemical conditions. These favourable physicochemical characteristics were reflected in the WQI values, which ranged from 89.92 to 96.47 at Station 1 and from 88.81 to 92.84 at Station 3, classifying both stations as clean under the NWQS of Malaysia. In contrast, Station 2 exhibited substantially degraded water quality, particularly during the first sampling period.

Although dissolved oxygen concentrations at this station ranged from 5 to 6 mg/L and remained within Class II, biochemical oxygen demand values were extremely high, reaching 77.5 mg/L during the first sampling event and remaining elevated at 20.4 and 27.2 mg/L in subsequent periods. These values were classified as Class V and indicate severe organic pollution. Chemical oxygen demand concentrations further supported this finding, with a peak value of 295 mg/L classified as Class V, followed by values of 31.7 and 32.2 mg/L corresponding to Class III. Elevated ammoniacal nitrogen concentrations ranging from 0.86 to 0.97 mg/L, classified within Classes III to V, further indicate substantial nitrogen loading at this location. Collectively, these parameters reflect excessive organic and chemical inputs that exceeded the natural assimilative capacity of the river at Station 2. In addition, a higher total suspended solids concentration of 51 mg/L recorded during the first sampling period indicates increased particulate input into the river. This observation is consistent with findings from the Tigris River study, which reported that higher suspended solids and turbidity levels were associated with surface runoff, riverbank erosion, and wastewater discharge, particularly during periods of increased flow (Al-Hamdani et al., 2019). The effects of this pollution were clearly reflected in the WQI results. Station 2 recorded a WQI value of 44.54 during the first sampling period, classifying the river as polluted and Class IV. Although subsequent WQI values improved to 63.70 and 71.57, corresponding to Class III and slightly polluted conditions, the river did not return to clean status. This pattern indicates persistent pollution pressure rather than a short-term disturbance. The reduction in WQI values at Station 2 was driven primarily by very low sub-index scores for biochemical oxygen demand and chemical oxygen demand, demonstrating the strong influence of organic and chemical pollution on overall river health. These findings are consistent with previous studies that have linked elevated BOD and COD levels to reductions in river assimilative capacity and subsequent ecological degradation. Faudzi et al. (2023) reported that BOD and COD concentrations exceeding the assimilative capacity of a river can reduce dissolved oxygen availability, thereby disrupting the balance and stability of aquatic ecosystems.

Although dissolved oxygen concentrations at Station 2 remained within acceptable limits, the extremely high BOD and COD values observed in this study suggest that the river segment is under significant stress and may be vulnerable to oxygen depletion under less favourable hydrological conditions. Furthermore, Kamarudin et al. (2020) reported that high BOD and COD concentrations are commonly associated with industrial effluent discharge and human activities in populated areas, which increase organic pollutant loads in river systems. This relationship provides a plausible explanation for the degraded water quality conditions observed at Station 2, which is located near areas of concentrated human and industrial activity. Overall, the results confirm that Sungai Besar, Tunjang exhibits heterogeneous water quality conditions influenced by localised anthropogenic pressures. While Stations 1 and 3 maintained stable and clean water quality throughout the study period, Station 2 emerged as a pollution hotspot characterised by severe organic and chemical contamination. The integration of physicochemical parameter analysis with WQI assessment effectively captured these contrasts and provided a clear representation of water quality variation along the Terusan Utara.

5.2 Conclusion

This study provides an updated and site-specific assessment of river water quality along Sungai Besar, Tunjang through the Terusan Utara by integrating physicochemical parameter analysis with classification based on the Malaysian WQI and NWQS. The findings revealed clear variation in water quality conditions along this medium-scale irrigation river, reflecting the influence of localised agricultural, industrial and domestic activities within a relatively short river stretch. Stations 1 and 3 consistently exhibited good water quality, with most parameters classified within Class I and Class II and WQI values indicating clean conditions throughout the study period. These results suggest that these river segments remain suitable for agricultural use and capable of supporting aquatic life. In contrast, Station 2 showed significantly degraded water quality, characterised by extremely high biochemical oxygen demand, chemical oxygen demand, and elevated ammoniacal nitrogen concentrations, which resulted in polluted to slightly polluted WQI classifications. These findings indicate that organic and chemical pollution at this location exceeded the natural assimilative capacity of the river. Overall, this study addresses the lack of recent and location-specific water quality data for irrigation rivers in northern Kedah and demonstrates the importance of station-based assessment in rivers subjected to mixed land use. The integration of physicochemical parameters with WQI evaluation effectively identified both stable and impacted river segments, providing essential baseline information to support river management, regulatory decision-making and sustainable freshwater use in agricultural regions.

REFERENCES

Al-Hamdani, R. M., Al-Kubaisi, A. R., & Al-Saffar, M. S. (2019). *Assessment of the water quality of the Tigris River in the city of Mosul*. Journal of Environmental Protection, 10(4), 447–460.

Amirul, A. (2024, July 25). DOE: Chemical leak from plant forced shutdown of Sungai Selangor treatment. *New Straits Times*.

Chidiac, S., El Najjar, P., Ouaini, N., El Rayess, Y., & El Azzi, D. (2023). A comprehensive review of water quality indices: History, models, attempts and perspectives. *Reviews in Environmental Science and Biotechnology, 22*, 349–395.

Department of Environment Malaysia. (2017). National River Water Quality Standards and River Water Quality Index.

Farah Safiah, A. N., Ahmad, A. K., & Nurhafizah Azwa, S. (2020). Water quality and diversity of benthic macroinvertebrates in Sungai Durian Perangin, Langkawi Island, Kedah, Malaysia. *Serangga, 25*(2), 10–23.

Faudzi, S. M. M., Mohd Soukhri, D. N., Mohd Akhir, M. F., Abdul Aziz, H., Mohd Kasim, M. Z., Zakaria, N. A., & Saad, N. A. (2023). Total maximum daily load application using biological oxygen demand, chemical oxygen demand, and ammoniacal nitrogen: A case study for water quality assessment in the Perai River Basin, Malaysia. Water, 15(6), 1227.

Godhaniya, M., Antaliya, K., Patel, R., & Kothari, C. (2024). Assessment of the ecological impact of pollution in the Damanganga River. *Acta Chimica Asiana, 7*(1), 417–425. https://doi.org/10.29303/aca.v7i1.201

Hafiz, M. A. H., Ismail, H. A. A., Zulkipli, L. Z., Manan, S. A., Mohd Ali, M., & Jansar, K. M. (2024). Hubungan mikroplastik dan kualiti air di Sungai Melaka, Melaka, Malaysia [Relationship between microplastics and water quality in Sungai Melaka, Melaka, Malaysia]. *Sains Malaysiana, 53*(9), 2071–2083.

Hamdan, A., Dawood, A., & Naeem, D. (2018). Assessment study of water quality index for Shatt Al Arab River and its branches, Iraq. *MATEC Web of Conferences, 162*, 05005. https://doi.org/10.1051/matecconf/201816205005

Haryati, S., Miskam, N., Yassin, A. M., & Musa, S. M. S. (2018). Status of river water quality in selected rural areas of Johor and its effects on life. *Asian Journal of Environment, History and Heritage, 2*(1).

Hashim, M., Ramli, E. Z., Setyowati, D. L., Nayan, N., Mat, Z., Said, H. M., & See, K. L. (2020). Impacts of land use on the water quality of Sungai Liwagu, Sabah. *Environment, 5*(19), 118–133.

Ida, R. A., & Md. Jamin, R. (2021). Water pollution study on the Orang Asli community at Tasik Chini, Pahang. *Universiti Malaysia Terengganu Journal of Undergraduate Research, 3*(2), 119–128.

Imelda, K., Longkop, S. A., Iqbal, M., Kapi, F. B., & Husain, I. H. (2025). Bibliometric analysis of river pollution impacts on aquatic ecosystems. *Biogenerasi: Jurnal Pendidikan Biologi, 10*(2).

Kamarudin, M. K. A., Wahab, N., Md Bati, S. N. A., Toriman, M. E., Saudi, A. S. M., Roslan Umar, & Sunardi. (2020). Seasonal variation on dissolved oxygen, biochemical oxygen demand and chemical oxygen demand in Terengganu River Basin, Malaysia. Journal of Environmental Science and Management, 23(2), 1–7.

Marselina, M., Kusumah, R. V., & Iskandar, I. (2022). Assessment of river water quality index methods for evaluating water quality status in the Citarum River, Indonesia. *Environmental Monitoring and Assessment, 194*(8), 577.

Najafzadeh, M., & Basirian, P. (2023). Evaluation of river water quality index using artificial intelligence and remote sensing data. *Remote Sensing, 15*(23), 2359.

Sim, S. F., & Tai, S. E. (2018). Assessment of a physicochemical indexing method for evaluation of tropical river water quality. *Journal of Chemistry, 2018*, 1–12.

Son, C. T., Giang, N. T. H., Thao, T. P., Nui, N. H., Lam, N. T., & Cong, V. H. (2020). Assessment of Cau River water quality using a combination of water quality and pollution indices. *Journal of Water Supply: Research and Technology AQUA, 69*(2), 160–172.

World Health Organization. (2012). *Guidelines for drinking water quality* (4th ed.). World Health Organization.

Xiao, L., Zhang, Q., Niu, C., & Wang, H. (2020). Spatiotemporal patterns in river water quality and pollution source apportionment in the arid Beichuan River basin of northwestern China using positive matrix factorization receptor modeling techniques. *International Journal of Environmental Research and Public Health, 17*(14), 5015. https://doi.org/10.3390/ijerph17145015