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COMPREHENSIVE ASSESSMENT OF PHYSICOCHEMICAL PARAMETERS AND WATER QUALITY IN THE SEMENYIH RIVER, SELANGOR, MALAYSIA

Nur Fazne IBRAHIM[1], Hafizan JUAHIR[1], Mohd Khairul Amri KAMARUDDIN[2,3], Raja Intan Naziha Raja Shamsul AZWAN[1], Mamoun Abdullah GHARAIBEH[4], Nadzifah YAAKUB[1*], Mohd Firdaus MAHAMAD ALI[5], Roger CREMADES[6]

[1] Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia
[2] East Coast Environmental Research Institute (ESERI), Universiti Sultan Zainal Abidin, 21300 Kuala Terengganu, Terengganu
[3] Faculty of Applied Social Science, Universiti Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Terengganu, Terengganu, Malaysia
[4]Department of Natural Resources and the Environment, Jordan University of Science and Technology, Irbid 22110, Jordan
[5] Faculty of Creative Technology & Heritage, University Malaysia Kelantan, 16300 Bachok, Kelantan
[6] Faculty of Environment, University of Leeds, Leeds, LS2 9JT, United Kingdom

Abstract
The Semenyih River is a significant water source for human consumption and ecological resilience. Despite the deteriorating quality of the river due to industrial effluents and untreated wastewater discharge, there is a lack of scientific assessment of the river's quality. The present study assesses the physicochemical parameters and Water Quality Index (WQI) of the Semenyih River. Sampling was carried out in October 2024, involving six study sites located along the Semenyih watercourses. Dissolved oxygen (DO) was within the range of 39.3% (St. 3: Sungai Buah) to 95.4% (St. 1: Raw water intake, Sungai Semenyih), showing flexibility in oxygen availability potentially attributed to biological and nutrient loads. Chemical Oxygen Demand (COD) varied notably, reaching a maximum in St. 6 of Sg. Lalang (68 mg/L), indicating high organic pollutant levels. Biochemical Oxygen Demand (BOD) proved biodegradation processes, while NH_4^+-N levels evidenced nutrient enrichment. The WQI of the Semenyih River varied from Class II to Class III, reflecting moderate to good water quality. Findings from this study highlighted the need for ongoing and consistent monitoring of the environment, particularly water quality, to protect public health and ensure the sustainability of the Semenyih River as an uncontaminated water source.

Keywords*: Physical chemical parameters; Water quality index; Sungai Semenyih*

Introduction

The Semenyih River Basin, located in Selangor, Malaysia, covers approximately 236.8 km², comprising 12 sub-basins and 28 catchment valleys [1]. The river basin offers a variety of land purposes, including human settlements, industrial estates, habitation, forested areas, and agricultural lands [2]. The Semenyih River, which stems from the Titiwangsa Mountain Range, flows southward and merges with the Langat River through the districts of Sepang and Hulu Langat [3]. The Semenyih River is a crucial water source for the Semenyih Dam, playing a prominent role in supplying the region, supporting both human consumption for drinking, cooking, and irrigation, and maintaining ecological balance. However, as the river flows through

[1] *Corresponding author: nadzifah@unisza.edu.my

several unclean areas of urban and industrial zones, it has become progressively threatened by pollution. Since the 1980s, rapid urbanization and development, along with agricultural activities and industrial expansion, have contributed to the discharge of untreated or partially treated effluents into the river, impacting the water quality for over 4 million people [4].

The water quality in the Semenyih River is worsening due to high loads of suspended solids, bacterial contamination, and toxic pollutants, specifically heavy metals [2]. This worsening of water quality not only impacts the aquatic ecosystems' biodiversity and causes significant health risks to communities relying on the river. It also puts additional pressure on the water treatment process, causing frequent disturbances in supplying water to domestic communities. Heavy metals, in particular, bear long-term environmental and health demands due to their persistence and bioaccumulation in aquatic organisms [5]. As the contaminated fish in the Semenyih River are consumed, toxic substances can accumulate and pass through the human food chain. Throughout the time, the risk of acquiring chronic health problems, including cancer and neurological damage, among local populations could increase.

The health of the river is critical to the local environment and populations relying on its resources. Water quality indicators, such as biology of microbial content (*Escherichia coli*), chemistry of heavy metals, nutrients (nitrates and phosphates), and organic matter, act as indicators of environmental health, highlighting potential risks to public health [6]. The government reports have frequently documented contamination scenarios in the Semenyih River, affecting the safety and availability of water supplied to thousands of residents. Heavy contamination episodes have significantly affected operations, leading to temporary shutdowns in water treatment processes, which allow for further investigations [7], [8]. Notably, between September and October 2016, the Semenyih River Water Treatment Plants (WTPs) were periodically shut down due to the ineffective treatment of chemically polluted and extremely turbid river water using conventional coagulation technology [7], [9], [10]. These scenarios highlighted the necessity for comprehensive risk evaluation of the basin and improved strategies for water resource management.

Despite various mitigation efforts, systematic and scientific investigations on the current status of physicochemical water parameters and the Water Quality Index (WQI) of the Semenyih River and its tributaries remain limited. Hence, the present study aims to focus on core water quality indicators such as pH, dissolved oxygen (DO), ammonium (NH_4), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS), exploring the dynamics governing the river's ecological condition. The overall findings will provide a comprehensive understanding of the physicochemical properties of the river. Additionally, evaluating the WQI over time allows for a quantifiable assessment of the river's health status.

Materials and Methods

Study area

This study encompasses six study sites situated along the Semenyih watercourses that flow into the Semenyih Dam (Fig. 1). The sampling points were: Station 1- Raw Water Intake Loji Rawatan Air (LRA) Sungai Semenyih, Station 2- Raw Water Intake LRA Semenyih 2, Station 3- Sg. Buah, Station 4- Sg. Semenyih, Station 5- Sg. Taman Indah, and Station 6- Sg. Lalang. These tributaries stream into the Semenyih Dam, which acts as a crucial treated water source, supplying the domestic areas. The chosen study sites were evaluated based on their proximity to various potential pollution sources, including industrial areas, multipurpose land use, waste disposal sites, and agricultural activities. These key factors possibly contribute to the water pollution, making these locations ideal for evaluating the water quality in the Semenyih River Basin.

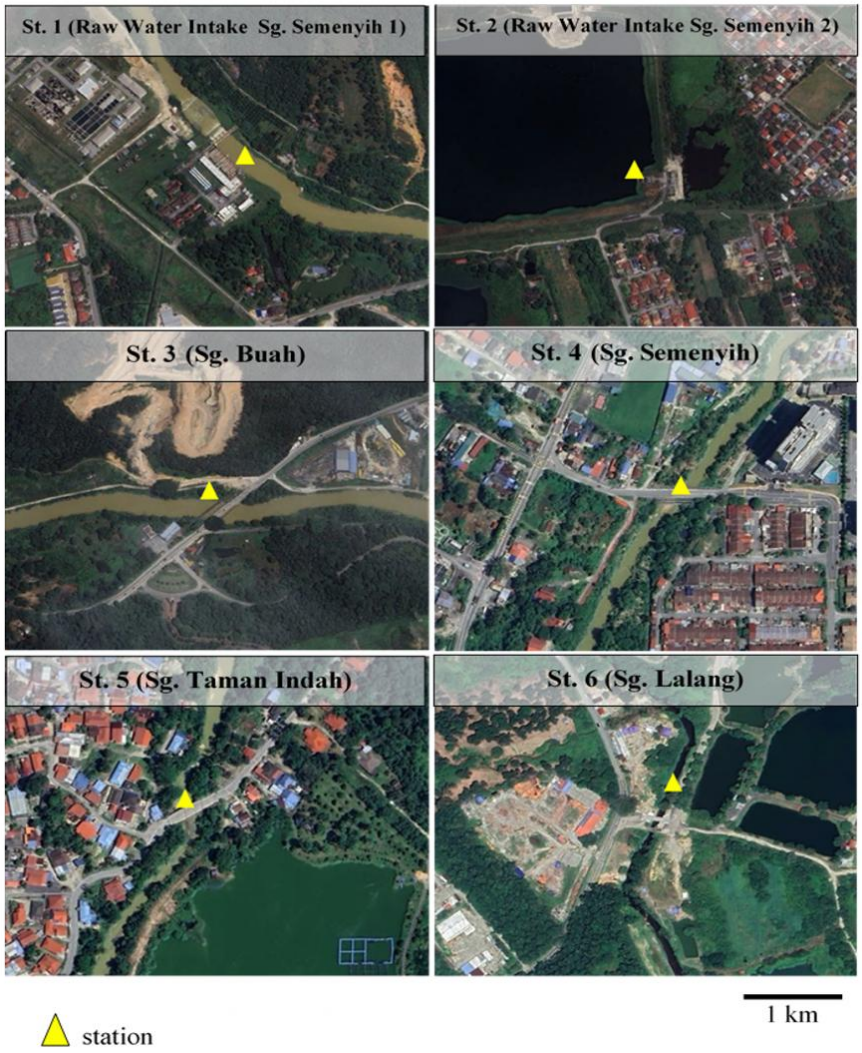

Fig. 1. Sampling location for Semenyih River. Station 1- Raw Water Intake LRA Sungai Semenyih (2°53'29.2"N 101°44'11.8"E); Station 2- Raw Water Intake LRA Semenyih 2 (2°53'26.0"N 101°43'39.4"E); Station 3- Sg. Buah (2°53'33.2"N 101°44'58.9"E); Station 4- Sg. Semenyih (2°57'31.5"N 101°50'57.1"E); Station 5- Sg. Taman Indah (2°59'55.7"N 101°52'30.0"E); and Station 6- Sg. Lalang (3°02'43.6"N 101°52'20.6"E). LRA = Loji Rawatan Air; Sg. = Sungai

Data Collection

Both in-situ and ex-situ experiments were conducted to assess the physicochemical parameters and water quality at these sampling locations. In-situ measurements, including dissolved oxygen (DO), pH, and ammonium (NH_4), were taken on-site using a YSI Multiparameter. Additionally, ex-situ laboratory analyses were performed to determine Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), and Total Suspended Solids (TSS) using the APHA (2017) method. The spatial water physical parameter data were visualized using a spatial model in ArcGIS. The Water Quality Index (WQI) is determined based on the National Water Quality Standards (NWQS) 2021. Table 1 provides an overview of the water quality parameters examined and the methods used.

Table .1 Analysis of water physicochemical parameters and method used

Water quality parameter	Unit	Method
pH Dissolved oxygen (DO)	mg/l	In situ measurement, YSI Handheld Multiparameter Probe
Chemical Oxygen Demand (COD)	mg/l	APHA (2017). Method 5220D (closed reflux, colorimetric). Measured using HACHDR 2800 Colorimeter at 620 nm
Biochemical Oxygen Demand (BOD)	mg/l	APHA (2017). Method 5210B (5-day incubation at 20°C). The final reading was measured using a YSI probe.
Total Suspended Solids (TSS)	mg/l	APHA (2017), Method 2540D (Turbidity estimation using a photometer, calibrated with gravimetric validation)
Ammoniacal Nitrogen (NH_3-N)	mg/l	Salicylate Method (USEPA Method 10023). (Measured using HACH DR2800 Colorimeter at 655 nm)

APHA = American Public Health Association
USEPA = United States Environmental Protection Agency

Water Quality Index (WQI)

The Water Quality Index (WQI) combines several water quality parameters into a solid value for evaluating water quality. The river water quality classification in Malaysia and its appropriateness for various uses or necessary treatment levels depend on the National Water Quality Standards (NWQS; Table 2). The WQI was formulated based on six key parameters: dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), ammoniacal nitrogen (NH_3-N), pH, and Total Suspended Solids (TSS), applying the following formula [11]:

$$WQI = (0.22\times SDO) + (0.19\times SBOD) + (0.16\times SCOD) + (0.15\times SNH3\text{-}N) + (0.16\times STSS) + (0.12\times SpH)$$

where: SDO, SBOD, SCOD, SAN, STSS, and SpH represent the sub-index values for each parameter obtained using standard WQI sub-index equations (Table 3).

Table 2. National Water Quality Standards for Malaysia-NWQS 2021

		Class				
Parameters	**Unit**	**I**	**IIA/IIB**	**III**	**IV**	**V**
pH		6.5–8.5	6–9	6–9	5–9	–
DO	mg/L	> 77	5–7	3–5	1–3	< 1
BOD_5	mg/L	< 1	1–3	3–6	6–12	> 12
COD	mg/L	< 10	10–25	25–50	50–100	> 100
SS	mg/L	< 25	25–50	50–150	150–300	> 300
AN	mg/L	< 0.1	0.1–0.3	0.3–0.9	0.9–2.7	> 2.7
Mn	mg/L	Natural level or absent	0.1	0.1	0.2	Level above IV
NO_2 (nitrite)	mg/L	Natural level or absent	0.4	0.4	–	Level above IV
NO_3 (nitrate)	mg/L	Natural level or absent	5	–	7	Level above IV
P	mg/L	Natural level or absent	0.1	0.2	–	Level above IV
WQI		**> 92.7**	**76.5–92.7**	**51.9–76.5**	**31.0–51.9**	**< 31.0**

Table 3. Equations for the determination of the parameter's sub-index

1	**Sub-index DO (ml/L)**	
	$x \leq 8\%$	$SIDO = 0$
	$x \geq 92\%$	$SIDO = 100$
	$8\% < x < 92\%$	$SIDO = -0.395 + 0.030 \times^2 - 0.00020 \times^3$
2	**Sub-index BOD (ml/L)**	
	$x \leq 5$	$SIBOD = 100.4 - 4.23x$
	$x > 5$	$SIBOD = 108e^{-0.055x} - 0.1$
3	**Sub-index COD (ml/L)**	
	$x \leq 20$	$SICOD = -1.33x + 99.1$
	$x > 20$	$SICOD = 103e^{-0.0157x} - 0.04x$
4	**Sub-index NH_3-N (ml/L)**	
	$x \leq 0.3$	$SIAN = 100.5 - 105x$
	$0.3 < x < 4$	$SIAN = 94e^{-0.573x} - 5\|x-2\|$
	$x > 4$	$SIAN = 0$
5	**Sub-index TSS (ml/L)**	
	$x \leq 100$	$SITSS = 97.5e^{-0.00676x} + 0.05x$
	$100 < x < 1000$	$SITSS = 71e^{-0.0016x} - 0.015x$
	$x > 1000$	$SITSS = 0$
6	**Sub-index pH**	
	$x < 5.5$	$SIpH = 17.2 - 17.2x + 5.02 \times^2$
	$5.5 \leq x < 7$	$SIpH = -242 + 95.5x - 6.67 \times^2$
	$7 \leq x < 8.75$	$SIpH = -181 + 82.4x - 6.05 \times^2$
	$x \geq 8.75$	$SIpH = 536 - 77.0x + 2.76 \times^2$

Note: X is the concentration in mg/L for all parameters except pH

Results and discussion

Water Quality Parameters

Table 4 shows the water physical parameter data collected from six sampling points along the Semenyih watercourses. Dissolved Oxygen (DO) levels showed significant variability across the different stations (Fig. 2A). Raw Water Intake LRA Sungai Semenyih had the highest DO (95.4%), indicating good oxygen availability in the water, which suggested minimal organic pollution. Conversely, Sungai Buah showed a significantly lower DO (39.3%), which could have indicated organic pollution or high biological activity consuming oxygen [12]. The Sungai Semenyih and Sungai Taman Indah also showed relatively good DO levels (82.3% and 79.5%, respectively), reflecting moderate water quality.

Table 4. Water quality for the Semenyih River. LRA= Loji Rawatan Air; Sg. = Sungai

Station	DO (%)	pH	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	NH4+ N (mg/L)
Raw Water Intake LRA Sungai Semenyih	95.4	7.1	0.556	52	5.32	0.88
Raw Water Intake LRA Semenyih 2	59.4	7.6	0.444	7	0.57	0.42
Sg. Buah	39.3	7.11	0.278	39	2.18	1.8
Sg. Semenyih	82.3	6.93	0.13	26	4.16	0.66
Sg. Taman Indah	79.5	7.03	0.606	21	3.48	0.67
Sg. Lalang	78.4	6.85	0.146	68	1.74	0.66

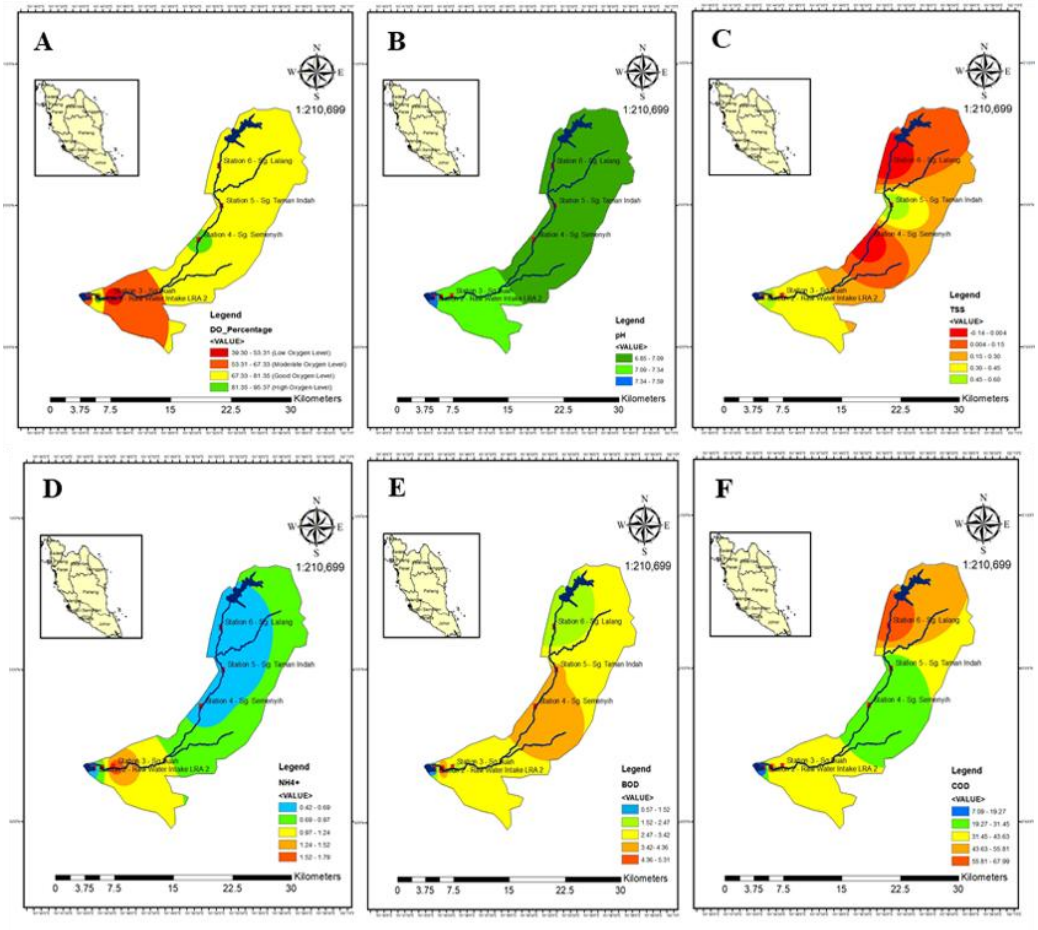

Fig. 2. Spatial model of water physicochemical parameters for Semenyih River. A. Dissolved Oxygen (DO) % B. pH C. Total Suspended Solid (TSS) D. NH_4^+N (mg/L) E. Biochemical Oxygen Demand (BOD) (mg/L) F. Chemical Oxygen Demand (COD) (mg/L)

In relation to pH variations, the results revealed significant seasonal and station differences ($p = 0.021$ and 0.036). pH values were slightly acidic to neutral across all sites (6.85 to 7.6) with no extreme variations (Table 4, Fig. 2B). Raw Water Intake LRA Semenyih 2 had the highest pH (7.6), indicating a slightly alkaline environment, while Sungai Lalang had the lowest pH (6.85), which could have suggested minor acidification in the water. The highest TSS value in Sungai Taman Indah (0.606 mg/L) suggests higher sediment loads in the water, which could potentially affect aquatic life (Table 4, Fig. 2C). Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) both serve as indicators of organic material in the water. Raw Water Intake LRA Sungai Semenyih, despite its high DO, had a relatively high COD (52 mg/L) and BOD (5.32 mg/L) (Table 4, Fig. 2F), suggesting the presence of organic pollutants that were being broken down by bacteria. However, oxygen levels remained high [12].

The upstream area of the Semenyih River, which had higher COD, was presumed to be impacted by the landfill site, fish farming, a concrete factory, a cemetery, and various industrial activities [2]. Additionally, the higher COD levels were found to correlate with elevated concentrations of heavy metals, such as Cd, Pb, and Zn, which were likely introduced into the river through runoff from these sources. The organic pollution from the landfill and cemetery, combined with the potential chemical discharge from industries and fish farms, contributed to the

accumulation of both organic matter and heavy metals, highlighting the interconnected nature of water quality degradation in the area. On the other hand, Sungai Buah, despite having a low DO, showed very low COD (7 mg/L) and BOD (0.57 mg/L) (Table 4, Figure 2E and F), possibly indicating the presence of more stable, non-biodegradable materials in the water [13].

Sungai Buah stood out with the highest ammonium level (1.8 mg/L) (Table 4, Figure 2D), which may be attributed to agricultural runoff or sewage contamination [14]. In contrast, the Raw Water Intake LRA Sungai Semenyih had a relatively low ammonium concentration (0.88 mg/L), which may indicate better quality in terms of nitrogen pollution. Water Quality Index (WQI) classified all stations within Class II (Figure 3), indicating relatively clean water with low to moderate pollutant levels, adequate dissolved oxygen levels and minimal toxic contamination. Class II waters are deemed suitable for conventional water treatment, as well as for sensitive aquatic life and recreational activities. However, the Raw Water Intake LRA Sungai Semenyih and Sungai Buah, with WQI values of 66.72 and 66.41, respectively, fall under Class III, indicating that polluted water was not suitable for direct contact or aquatic life without treatment.

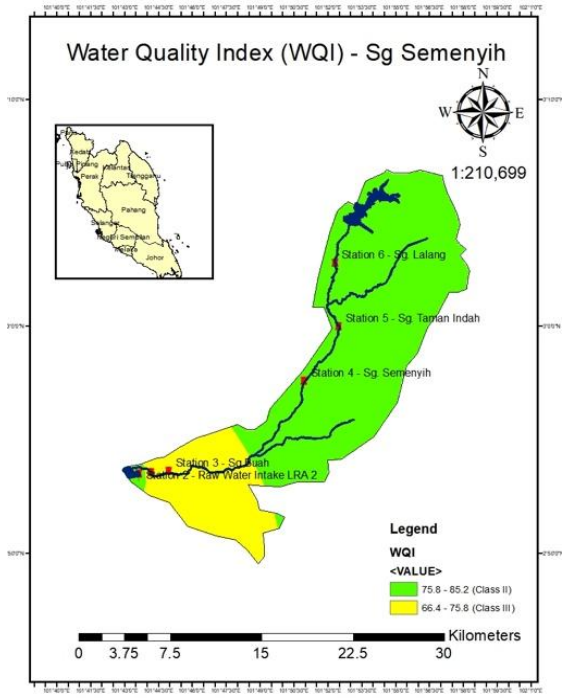

Fig. 3. Water Quality Index (WQI) for Semenyih River

In comparison with data from the Department of Environment (DOE) and previous studies from 2015 to 2023, the WQI of the Semenyih River has fluctuated between Class II (clean to slightly polluted) and Class III (moderately polluted) (Table 5). From 2015 to 2017, a shift from Class II (WQI 81) to III (WQI 76) was observed, indicating a decline in water quality, likely due to intense anthropogenic pressures such as industrial discharge and urbanization. In 2018, [13] recorded a WQI of 80.95, bringing the river back into Class II, suggesting temporary improvements. In 2019, mixed readings were detected (WQIs of 77 and 75) between DOE 2021 and [14], both of which placed the Semenyih River in Class III, highlighting a site-specific variation or differing sampling periods within the same year.

Table 5. Water Quality Index (WQI) for the Semenyih River

Year	WQI	Class	References
2015	81	II	DOE 2021
2016	76	III	DOE 2021
2017	76	III	DOE 2021
2018	80.95	II	[14]
2019	77, 75	III	DOE 2021, [15]
2020	83, 50.9	II, III	DOE 2021, [16]
2021	87, 51.9–76.5	II, III	DOE 2021, [2]
2022	86	II	DOE 2021
2023	86	II	DOE 2021

In 2020, a disparity in the WQI values was detected between DOE 2021 and [14]—83 (Class II) and 50.9 (Class III), highlighting variability along the river's course or sampling inconsistencies. The year 2021 again shows mixed WQI conditions, as indicated by DOE 2021 and [2]. While the DOE records a healthy WQI of 87 (Class II), [2] the report covers a broader range, from 51.9 to 76.5, spanning Class III to lower Class II. This reinforces the presence of localized pollution hotspots despite an overall improvement. The years 2022 and 2023 consistently show a WQI of 86, firmly placing the river in Class II, suggesting a stabilization in water quality conditions, possibly due to better enforcement of environmental regulations and community awareness initiatives.

Overall, the water quality of the Semenyih River varied significantly across different locations. Raw Water Intake LRA Sungai Semenyih exhibited relatively high oxygen levels but higher organic contaminants. Sungai Buah appeared to have substantial nitrogen pollution. In contrast, other sites, such as the Sungai Semenyih River and Sungai Taman Indah, exhibited moderate water quality, balancing oxygen levels with organic loads and ammonium concentrations. Further monitoring and analysis were recommended to understand better the sources of contamination and the overall health of these water bodies.

Conclusion

This study successfully assesses the physicochemical parameters and overall water quality level of the Semenyih River. The results revealed notable differences among sampling sites, documenting the possible influence of both anthropogenic and natural impacts on river health. Water physical parameters of DO, pH, and TSS levels marked moderate to good water quality at most stations, particularly at Sungai Semenyih (St. 4) and Sungai Taman Indah (St. 5), while Sungai Buah (St. 3) recorded high NH_3N concentrations and very low DO, suggesting biological and nutrient pollution possibly stemming from agricultural activity and domestic sewage runoff. At the Raw Water Intake LRA Sungai Semenyih (St. 1), despite a high DO level, the elevated COD and BOD readings indicate organic contamination, possibly attributed to the active industrial and urban influences in the upstream areas.

In most stations, the WQI analysis is under Class II, indicating relatively clean water conditions that support aquatic life, but water treatment is needed for safe human consumption. In the case of stations declining to Class III, it reflects pollution impacts at specific sites. A long-term comparison from 2015 to 2023 documented an alternate WQI pattern between Class II and III in parallel with various types of human activities and improvements in environmental management practices.

Overall, the Semenyih River has been documented to periodically recover yet remains threatened by contamination from anthropogenic activities, including industrial waste, landfill effluents, and agricultural inputs. Findings from this study suggest the need for continuous monitoring, tighter rules and regulations on pollutant input from authorities, and integrated watershed management strategies. The study also enhances the understanding of the dynamic

interactions between physicochemical parameters and anthropogenic impacts, thereby forming a scientific and fundamental basis for sustainable river basin management.

Acknowledgments

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