Jurnal Kejuruteraan 36(6) 2024: 2683–2692
https://doi.org/10.17576/jkukm-2024-36(6)-37

Water Quality Assessment in Wet Season of Langat River, Selangor, Malaysia

Muhammad Amir Danish[a], Tay Chia Chay[b,c], Muhammad Izzat Nor Ma'arof[d], Girma T. Chala[e] & Nurul Fariha Lokman[a,c*]

[a]School of Civil Engineering, College of Engineering, Universiti Teknologi MARA,

40450 Shah Alam, Selangor, Malaysia

[b]Faculty of Applied Sciences, Universiti Teknologi MARA,
40450 Shah Alam, Selangor, Malaysia

[c]myBioREC, School of Civil Engineering, College of Engineering, Universiti Teknologi MARA,
40450 Shah Alam, Selangor, Malaysia

[d]Department of Mechanical Engineering, Faculty of Engineering and Quantity Surveying,
INTI International University, 71800 Nilai, Negeri Sembilan, Malaysia

[e]Department of Mechanical Engineering (Well Engineering),
International College of Engineering and Management, Muscat, Oman

[*]Corresponding author: nurul_fariha@uitm.edu.my

Received 29 February 2024, Received in revised form 5 August 2024
Accepted 6 September 2024, Available online 30 November 2024

ABSTRACT

Water quality assessment is crucial for human and environmental health, but studies often face challenges with missing or incomplete data across seasons. This study evaluated the water quality of the Langat River in Selangor, Malaysia, during the wet season, focusing on Water Quality Index (WQI), water classification, and trace metal concentrations. The WQI model, used by Malaysia's Department of Environment (DOE), serves as a tool for assessing water quality. Water samples were taken from three sites: Kampung Hulu Kuala Pansoon (upstream), Pekan Bt 18 (midstream), and Nanding (downstream). Results showed significant water quality degradation from upstream to downstream, with WQI of 88.01 (Class II) at Kampung Hulu Kuala Pansoon, while both Pekan Bt 18 and Nanding fell into Class III with WQI of 76.50 and 71.68, respectively. While Class II indicates clean water, Class III reflects slightly polluted conditions based on the National Water Quality Standard (NWQS). Population density and land use types were identified as factors in this decline. Trace metal analysis as arsenic, chromium, cadmium, lead, aluminum, zinc, and manganese were present downstream. Although most levels were below NWQS limits, aluminum at 0.071mg/l exceeded permissible values, and manganese 0.09 mg/l detected to be close to the allowable threshold. The small dataset limits accuracy but adds insight to water assessment in wet season. Future studies need more sampling locations and hydrological data. In supporting SDG 6, continuous collaboration with state authorities aims to prevent degradation, ensure Class IIA compliance, and protect water supplies for Selangor's Water Treatment Plants.

Keywords: Water Quality Index (WQI); Langat River; heavy metals; water classification; wet season

INTRODUCTION

River connectivity and floodplain interactions can significantly influence water quality through various biogeochemical processes. Water flowing onto the floodplain releases carbon, which provides energy to the food chain (McInerney et al. 2023). Rivers act as conduits to transfer carbon from land to aquatic bodies and also release it into the atmosphere via CO_2 degassing (Xu et al. 2024). Sudden increase in floodplain wetlands and rainfall intensity during wet season may disturb the carbon cycle and increase the water level. The high rainfall contributes to bank erosion and channel instability such as slope failure and large volume of debris in the river. In the long run, these factors may increase the risk of flooding. It is stated by Ching et al. (2015) that the flood events and high amount of rainfall are the key factors affecting the river water quality. The Water Quality Index (WQI) is a valuable measuring tool for controlling river water pollution and ensuring water quality's sustainability (Pairan et al. 2023; Supardi et al. 2023). Nonetheless, these studies have also proposed the improvement of WQI through their respective research. The WQI determines if river waters are acceptable for agriculture, aquaculture, recreation, and residential usage.

In Malaysia, surface water is the most accessible but most susceptible to pollution from domestic and other sources. Malaysian water quality standards require class IIA WQI for conventional treatment. Thus, surface water must be monitored and assessed carefully to stay in that class for domestic use. Malaysian rivers are polluted by sewage, discharges from small and medium-sized companies without effluent treatment facilities, and land removal and earthworks. Langat River in Selangor state is one of the main raw water resources for drinking, recreational, industrial and agricultural purposes (Ahmed et al. 2021). The Langat River is the main river draining at a heavily populated area and has been a source of hydropower and flood control for half of the state's population for 40 years (Juahir et al. 2011). However, the Langat River Basin is also affected by surface water contamination. Anthropogenic activities such as uncontrolled land clearing, animal husbandry, and domestic sewage disposal also fouled the river with suspended solids. Continuous development and rapid urbanization along the river had altered rainwater-permeable soil surfaces. All the associated factors result in deterioration of water quality parameters.

A total of seven (7) water treatment plants (WTP) in Selangor namely: (i) Sg Langat, (ii) Bukit Tampoi, (iii) Cheras Batu 11, (iv) Salak Tinggi, (v) Sg Pansoon, (vi) Sg Serai, and (vii) Sg Lolo attain their raw water supply solely from the Langat River. It should be noted that these WTPs are at the risk of being temporarily closed if the Langat River is contaminated. In fact, such an incident did happen on October 8, 2016, when the Langat WTP and Cheras WTP were temporarily closed due to foul odours from the Semantan River in Pahang (Bernama, 2016). The temporary closure of WTP shall result in water supply cut-off and the closure of Langat WTP and Cheras WTP as aforementioned had caused cut-off in Cheras, Kuala Lumpur, and Petaling. Henceforth, it is a best practice to first ensure that the WQI in most Malaysian rivers is in compliance with the water quality standards. The Langat River's WQI was assessed to be Class IIA, which requires conventional treatment before drinking. However, the Langat River's midstream raw water intake sites, including Langat, Cheras, and Bukit points, are Class III, which need to undergo significant treatment before drinking (Ahmed et al. 2022).

Several studies have examined water quality in the Langat River, Malaysia, using modelling analysis. As far as we are aware, there has been limited research on the seasonal variations (dry and wet seasons) of Langat River using laboratory analysis of actual samples. This study aimed to determine the Water Quality Index (WQI), classify river water quality, and measure trace metal concentrations at various points along the Langat River. The study will focus on wet seasons where the intensity of rainfall is higher. Results of this study could be useful as additional information in supporting State authority in mitigating the unhealthy river water classification that is the main surface water resources.

METHODOLOGY

COLLECTION OF WATER SAMPLES

The Langat River has a total catchment area of approximately 1,815km^2. It lies within latitudes 2˚40' M 152" N to 3˚16' M 15" and longitudes 101˚19' M 20" E to102˚1' M 10" E. In this study, three (3) sampling locations have been selected for

collecting water samples which were: (i) Kampung Hulu Kuala Pansoon (Upstream) (3°12'29.8"N 101°51'40.9"E), (ii) Pekan Bt 18 (Midstream) (3°09'24.3"N 101°50'38.1"E), and (iii) Nanding (Downstream) (3°05'45.4"N101°48'04.3"E) as shown in Figure 1. The river flows from upstream to downstream. The selection of the sampling locations is accessible and safe for collecting the samples. This includes considering the ease of access by individual vehicles. This is to ensure that the sampling process does not pose undue risk to the samplers. The selection of sample points at the upstream, which is Kampung Hulu Pansoon, provides a baseline measurement of the water quality before it encounters any potential contaminants or changes. This helps in understanding the natural state of the river and the impact of any downstream activities or pollutants. Furthermore, Sampling point collected at Kampung Hulu Kuala Pansoon is a designated recreational area for family gatherings. This sampling point allows for the evaluation of potential impacts from recreational activities on water quality. The water sample was collected at Pekan Bt 18, an area surrounded by residential units, homestays, and nearby to Jerang Agro Farm. This sampling point allows for a comprehensive assessment of potential contaminants from multiple sources, including residential waste, runoff from homestays, and agricultural discharge from the nearby farm. As for the downstream part, Nanding being surrounded by a highly populated area, presents different challenges and considerations compared to the less populated area. Nanding's high population density means there is likely greater human activity, which can contribute to various pollutants entering the river bodies. The water samples were collected in the wet season only due to the time frame limitation for the study. The samplings were conducted for the duration of two (2) months (Nov-Dis 2022), with three (3) samples for each location and for four (4) sampling days. The water samples collected from each location of the river were kept in polyethylene bottles made of opaque material. This precautionary action was undertaken to avoid sunlight from making contact with the samples, thus, causing reaction and influencing the oxygen content of the sample. All samples were preserved in an ice box before being transported back to the laboratory. Sample preservation is required to maintain the original composition of water samples and to minimize changes in chemical composition during transportation to the laboratory. The water samples collected were used within 24 hours to ensure that the characteristics of water remain consistent. The WQI parameters testing was conducted in Environmental Laboratory 1, School of Civil Engineering, College of Engineering, UiTM Shah Alam and in situ testing at each sampling point.

FIGURE 1. Map of sampling point location along the Langat River

LABORATORY AND IN-SITU TESTING

There were six (6) physicochemical parameters measured for WQI, which were: (i) Ammoniacal Nitrogen (AN), (ii) Biological Oxygen Demand (BOD), (iii) Total Suspended Solid (TSS), (iv) Chemical Oxygen Demand (COD), (iv) Dissolved Oxygen (DO) and (v) pH. The assessments of AN (APHA method 4500-NH_3 B and C), BOD (APHA method 5210B), TSS (APHA method 2540D) and COD (APHA method 5220 D) were conducted in the Environmental Laboratory 1. All the apparatus was cleaned with distilled water beforehand. Meanwhile, the DO and pH were conducted in-situ using portable HORIBA instruments (HORIBA 2013). Apart from that, the heavy metals were evaluated by convenient Inductive Coupled Plasma-Mass Spectrometry (ICP-MS) at i-CRIM Centralised Lab, Centre for Natural and Physical Laboratory Management, Universiti Kebangsaan Malaysia.

WATER QUALITY INDEX (WQI)

The classification of Water Quality Index (WQI) was determined by using the formula developed by the Department of Environment (DOE) Malaysia. The data on water quality are summarized in Equation 1 (DOE, 2023):

$$WQI = (0.22*SIDO) + (0.19*SIBOD) + (0.16*SICOD) + (0.15*SIAN) + (0.16*SISS) + (0.12*SIpH) \quad (1)$$

Where; WQI = Water Quality Index
SIDO = Subindex DO (% saturation)
SIBOD = Subindex BOD
SICOD = Subindex COD
SIAN = Subindex AN
SISS = Subindex SS
SIpH = Subindex pH

The required subindex of each parameter in Equation 1 can be calculated from Table 1. Table 2 and Table 3 display the classification for every parameter, while Table 4 will determine the final status of the Langat River following to the National Water Quality Standards (NWQS).

TABLE 1. Sub index of water quality parameters

DO	$X \leq 8$	SIDO = 0
	$X \geq 92$	SIDO = 100
	$8 < X < 92$	$SIDO = -0.395 + 0.03X^2 - 0.0002X^3$
BOD	$X \leq 5$	$SIBOD = 100.4 - 4.23X$
	$X > 5$	$SIBOD = 108e^{-0.055x} - 0.1X$
COD	$X \leq 20$	$SICOD = 99.1 - 1.33X$
	$X > 20$	$SICOD\ 103e^{-0.0157x} - 0.04X$
AN	$X \leq 0.3$	$SIAN = 100.5 - 105X$
	$0.3 < X < 4$	$SIAN = 94e^{-0.573X} - 5(X-2)$
SS	$X \leq 100$	$SISS = 97.5e^{-0.00676X} + 0.05X$
	$100 < X < 1000$	$SISS = 71e^{-0.0016X} - 0.015X$
	$X \geq 1000$	SISS = 0
pH	$X < 5.5$	$SIpH = 17.2 - 17.2X + 5.02X^2$
	$5.5 \leq X < 7$	$SIpH = -242 + 95.5X - 6.67\ X^2$
	$7 \leq X < 8.75$	$SIpH = -181 + 82.4X - 6.05\ X^2$
	$X \geq 8.75$	$SIpH = 536 - 77X + 2.76\ X$

TABLE 2. DOE Water Quality Index Classification

Sub Index & Water Quality Index	Index Range		
	Clean	Slightly Polluted	Polluted
BOD	91 - 100	80 - 90	0 - 79
AN	92 - 100	71 - 91	0 - 70
SS	76 - 100	70 - 75	0 - 69
WQI	81 - 100	60 - 80	0 - 59

TABLE 3. DOE Water Quality Classification based on Water Quality Index

Parameter	Unit	Class				
		I	II	III	IV	V
AN	mg/l	< 0.1	- 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
BOD	mg/l	< 1	1– 3	3 - 6	6 – 12	> 12
COD	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
DO	mg/l	> 7	5 – 7	3 - 5	1 - 3	< 1
pH	-	> 7	6 - 7	5 - 6	< 5	> 5
TSS	mg/l	< 25	25 - 50	50 - 150	150 - 300	> 300
WQI	-	< 92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	> 31.0

TABLE 4. National Water Quality Standards

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

RESULTS AND DISCUSSION

SUBINDEX PARAMETERS FOR SAMPLING LOCATIONS

Table 5, Table 6, and Table 7 show the subindex parameter result for every laboratory testing and in-situ testing of Kampung Hulu Kuala Pansoon (Upstream), Pekan Bt 18 (Midstream) and Nanding (Downstream), respectively. All the calculated subindex values were substituted in the equation 1 to determine the WQI for each sampling location. Every data for each sampling date is the average of the three readings in the wet season. The DOE Water Quality Index Classification (see Table 2) served as the basis for comparison.

The average value of DO for upstream, midstream and downstream areas are 12.40 mg/l, 11.60 mg/l and 11.60 mg/l, respectively. All three (3) sample locations fall under class I. According to National Water Quality Standards (NWQS), the best value for DO is greater than 7 mg/l, which is suitable for aquatic living (Shaghaghi et al. 2024). Any slight drop or increase in value of DO for every sampling day from each sampling location is due to variation in the temperature of water, the movement of water flow and the presence of air in the forms of current.

The average BOD for upstream area is 5.44 mg/l and falls under class III. The midstream and downstream areas display average BOD of 7.38 mg/l and 9.24 mg/l, respectively and are classified under Class IV. The higher the BOD reading, the more organic matter in the water indicates a greater need for oxygen and denotes poorer water quality. Apart from that, the amount of BOD is also affected due to pH and the presence of nutrients in the water. High BOD levels in the long run indicate significant pollution and can lead to decreased DO which affects aquatic life and water usability (Sinurat et al. 2024).

Meanwhile, the average values of COD for upstream, midstream and downstream areas were 6 mg/l, 23.23 mg/l and 38.25 mg/l, respectively. The COD in upstream, Kampung Hulu Kuala Pansoon falls under class I while the other two (2) locations fall under class II. The class of COD decreases as the water flows from upstream to downstream indicating clean to slightly poor water quality due to a higher dense population area and decomposition of organic and inorganic substances in the waste produced.

The average value of TSS for Kampung Hulu Kuala Pansoon is 13mg/l that illustrates class I, Pekan Bt 18 is 130.25 mg/l falls under class III and Nanding is 194.75 mg/l falls under class IV. The trend shows a decrease in classification of water as the river flows to a higher dense population. Various pollutants, including silt, decomposing plant and animal species, industrial waste, and sewage entering the river from nearby sources, might result in high TSS levels. Similar findings by Abidin et al. (2018) show a change of TSS in Langat River with water classification variation from Class I to Class III, from upstream to downstream.

The average pH based on the three (3) locations, from upstream, midstream and downstream were found at 6.65, 6.38 and 6.02, respectively. The average value is in the range of 6.0 to 7.0 that is classified to Class II. This indicates that the pH readings are stable but in mild acidic condition. However, the value is still close to the neutral pH at 7. The mild acidic state was affected due to natural and external factors. Natural effects occur due to interactions with surrounding rocks, rain precipitation and the presence of high organic matter. As for external factors, it was due to the runoff from the local roads that carry organic compounds that have come from plants and animals. Similar findings by Liang et al. (2020) reported the Johor River in Malaysia generally meets Class II water quality standards for pH, but considered safe for human and aquatic consumption where the pH levels were within the acceptable range.

TABLE 5. Result of subindex parameters for Kampung Hulu Kuala Pansoon (Upstream)

WQI Parameter	2/11/22	30/11/22	6/12/22	21/12/22	Average	Water Classification
	1st sampling	2nd sampling	3rd sampling	4th sampling		
DO (mg/l)	10.07	16.80	10.07	12.73	12.4	Class I
BOD (mg/l)	5.81	5.59	4.85	5.51	5.44	Class III
COD (mg/l)	4	11	3	6	6	Class I
TSS (mg/l)	13	17	10	12	13	Class I
pH	7.85	5.77	5.75	7.23	6.65	Class II
AN (mg/l)	0.37	0.29	0.27	0.21	0.29	Class II

TABLE 6. Result of subindex parameters for Pekan Bt 18 (Midstream)

WQI Parameter	2/11/22	30/11/22	6/12/22	21/12/22	Average	Water Classification
	1st sampling	2nd sampling	3rd sampling	4th sampling		
DO (mg/l)	9.56	15.19	9.56	12.06	11.6	Class I
BOD (mg/l)	7.78	7.48	7.12	7.13	7.38	Class IV
COD (mg/l)	11	28	31	23	23.25	Class II
TSS (mg/l)	184	120	112	105	130.25	Class III
pH	7.85	5.77	5.75	6.16	6.38	Class II
AN (mg/l)	2.06	0.45	0.5	0.27	0.82	Class III

TABLE 7. Result of subindex parameters for Nanding (Downstream)

WQI Parameter	2/11/22	30/11/22	6/12/22	21/12/22	Average	Water Classification
	1st sampling	2nd sampling	3rd sampling	4th sampling		
DO (mg/l)	8.86	17.24	8.86	11.46	11.61	Class I
BOD (mg/l)	9.4	8.62	9.16	9.76	9.24	Class IV
COD (mg/l)	15	46	47	45	38.25	Class II
TSS (mg/l)	205	194	207	173	194.75	Class IV
pH	6.64	5.60	6.46	5.39	6.02	Class II
AN (mg/l)	2.22	0.49	0.21	0.50	0.86	Class III

The average value of AN for Kampung Hulu Kuala Pansoon was 0.29 mg/l under Class II. The average AN for Pekan Bt 18 is 0.82 mg/l and Nanding was 0.86 mg/l which falls under Class III. In the water quality assessment of Tekala River, Selangor, Malaysia by Hanafiah et al. (2018), the escherichia coli levels are correlated with higher variation of ammoniacal nitrogen, temperature, and dissolved oxygen. Meanwhile, it is reported by Gafri (2018) the AN within classes II, IV, and V Anak Air Batu River in UM Kuala Lumpur, Malaysia due to the significant presence of microbes that was unsuitable for human consumption. The classification of AN is declining in the current study in relation to the dense population from upstream to downstream areas along the Langat River.

Sampling stations in the study area of the Langat River in Basheer et al. (2017) is located between latitudes 2°58’48.6” N and longitudes 101°47’07.1” E. The location of their chosen area is situated below the downstream area in the current study. The average WQI for each parameter for DO, BOD, COD, TSS, pH and Ammoniacal Nitrogen were reported at 6.2 mg/l, 1.53 mg/l, 9 mg/l , 0.008 mg/l , 0.24 mg/l and 5.91 – 6.79. In comparison to the current study, all the average WQI values in Basheer et al. (2017) for each parameter are lower. It can be summarised that after five years, the average WQI values have increased.

WATER QUALITY ANALYSIS

The WQI results, water classification and pollution status of each sampling point were tabulated as in Table 8. The WQI for Kampung Hulu Kuala Pansoon (Upstream) on the first, second, third and fourth sampling dates were 89.98, 84.21, 88.27 and 89.6, respectively with an average of 88.01. Based on the DOE guidelines, the results of all the upstream sampling datas indicate class II which is clean. Similar WQI result at the same sampling location was recorded of 92.23±6.60 from 2005-2015 (DOE, 2015).

TABLE 8. Result of WQI for all sampling points

	Sampling Location											
	Kampung Hulu Kuala Pansoon (Upstream)				Pekan Bt 18 (Midstream)				Nanding (Downstream)			
Month	Nov		Dec		Nov		Dec		Nov		Dec	
WQI	89.98	84.21	88.27	89.60	72.96	77.25	77.06	77.82	69.96	71.99	72.82	71.92
Average WQI	88.01				76.50				71.68			
Water Classification	Class II				Class III				Class III			
Pollution Status	Clean				Slightly Polluted				Slightly Polluted			

The WQI for Pekan Bt 18 (Midstream) on the first, second, third and fourth sampling dates were 72.96, 77.25, 77.06 and 77.82, respectively, with an average of 76.50. From these results all the sampling falls under class III, at the border line which is slightly polluted. Ahmad et al. (2015) study on the same upstream and midstream areas as in this study. The reported average WQI at the upstream area range between 91.5 to 93.55 (Class I to Class II) and in the midstream area were in the range of 76.03 and 62.9 (Class III).

The WQI for Nanding (Downstream) on the first, second, third and fourth sampling dates were 69.96, 71.99, 72.82 and 71.92, respectively, with an average of 71.68. From these results all the sampling is classified in class III which is slightly polluted. The study area in Basheer et al. (2017) is near to the downstream area in this current study. Similar sampling time which is the wet season reported the WQI was in class III and is aligned with the findings of the current study. The clean water status in Kampung Hulu Kuala Pansoon (upstream) is achieved because it is a less developed area, hilly topography with the dense tropical forest compared to the other two sampling locations. This upstream area implies it used for recreational purposes.

The type of land used for each sampling point was listed in Table 9. Based on the observation at sites, the locations starting from Kampung Hulu Kuala Pansoon (Upstream), Pekan Bt 18 (Midstream) to Nanding (Downstream) can be categorized as less dense population, medium dense population and high dense population, respectively. The water quality degrades as the river flows into a highly dense population. A dense population can significantly affect the water quality of a river due to increased human activity, leading to higher levels of pollutants such as domestic sewage, industrial discharges, and urban runoff. The increase in industrial operations is to fulfill the needs of population growth, which may release wastewater and emissions into the environment (Anh et al. 2023).

It was found on site that there were pipes and drains that flow the discharge of wastewater directly from residential and development activities into Langat River. It is also reported by Basheer et al. (2017) that the human activities surrounding the Langat River, including construction, manufacturing plants, sand mining, and domestic waste disposal, have a significant impact on the water quality. Jamal et al. (2023) determined water quality of Sungai Masai in Johor and can be classified as Slightly Polluted or Class III, with WQI in the range from 59.34 to 74.47. The land use for industrial, fishery and residential areas has led this river to be contaminated. The water classification and type of land utilization are similar to the current study, in which the river water can be used as drinking water, but it requires further treatment before consumption.

TABLE 9. Type of land uses for each sampling point

Sampling point	Type of land uses
Kg Hulu Kuala Pansoon (Upstream)	Residential area & recreational area
Pekan Bt 18 (Midstream)	Residential area & commercial area
Nanding (Downstream)	Industrial area, residential area & commercial area

TRACE METALS IN LANGAT RIVER

Table 10 shows permissible limits of heavy metals according to National Water Quality Standard (NWQS). The result display in Figure 2 will be compared to the permissible limits. Figure 2 shows the mean of trace metals in Langat River for Kampung Hulu Kuala Pansoon (Upstream), Pekan Bt 18 (Midstream) and Nanding (Downstream). The mean concentrations in the three areas compared with the National Water Quality Standard (NWQS) in Table 10. The results illustrate that for the upstream area, only lead (Pb) (0.003 mg/l) and aluminium (Al) (0.005 mg/l) metals were presence but way below standard permissible values of NWQS. No appreciable amount of arsenic (As), chromium (Cr), cadmium (Cd), zinc (Zn) and manganese (Mn) were found in that recreational area. The midstream area shows a similar trend of very minimal Cd (0.001 mg/l), Pb (0.01 mg/l), Al (0.01 mg/l) and Mn (0.04 mg/l) presence. No trace metals that exceed the permissible limits of NWQS. However, the downstream area shows all the trace metals of As, Cr, Cd, Pb, Al, Zn and Mn at 0.016, 0.009, 0.005, 0.04, 0.071, 0.02 and 0.09 mg/l, respectively. Only Al is detected to be beyond the permissible limit of NWQS, while Mn was detected to be close to the allowable threshold. Lim et al. (2013) reported a higher Al concentration of 5.192 mg/L in the downstream section of the Langat River, rendering it unsuitable for direct drinking consumption without prior treatment. Similarly, Aris et al. (2015) reported Mn was found at 0.20 mg/l which exceeding the permissible limits. However, the comparative value of Al and Mn in the current study with the two previous studies, indicates an improvement in the water quality of the Langat River.

Interestingly, Alam et al. (2015) study seasonal variation of trace element pollution in Langat River using multivariate estimation analysis. In the study, the analysed metals of As, Cd, Cr, Pb, Ca, Fe, K, Mg and Na shows the highest concentration in dry season compared to wet season. In relation to the study by Olıas et al. (2004), the higher concentrations of heavy metals observed during the dry season can be attributed to high evaporation rates and elevated anthropogenic activities. The dilution effect during the flood season, driven by the Northeast monsoon, led to a reduction in metals concentrations (Li & Zhang 2010).

In the current study, the heavy metals concentrations in the downstream area were arranged in decreasing order of Mn>Al>Zn>As>Cr>Pb>Cd. The mean of trace heavy metals is related to water classification in the previous sub-section where the midstream and downstream area shows status of slightly polluted (Class III). It should be noted also that the WQI of midstream is at the border line between clean and slightly polluted water status, and thus, the low trace metals concentrations are aligned. Basheer et al. 2017 reported the presence of Mn, Zn, Fe and Cd in the downstream of Langat River. The heavy metals predominantly originated from the industrial and construction activities, but still within the low levels. As far as industrial waste is concerned at the downstream area (see Table 9), it can be summarized that the presence of heavy metals levels in Langat River is not alarming. Nevertheless, the presence of heavy metals identified in the current study and other similar studies should be closely monitored to prevent further deterioration of water quality in the Langat River in the future.

TABLE 10. Permissible limits in National Water Quality Standard (NWQS)

Heavy Metals	Permissible limits (mg/l)
As	0.40
Cr	0.05-0.10
Cd	0.01
Pb	0.05-5
Al	0.06
Zn	0.40
Mn	0.10

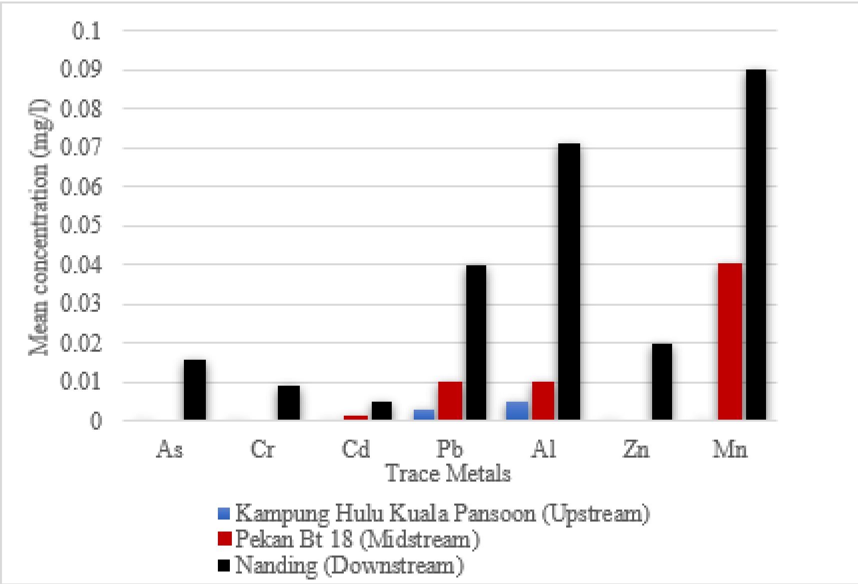

FIGURE 2. Trace metals in Langat River

CONCLUSION

The findings indicate a clear degradation of water quality in the Langat River as it flows from Kampung Hulu Kuala Pansoon (Upstream) to Nanding (Downstream). Key water quality parameters, including BOD, COD, and AN, showed significant decreases downstream, highlighting the impact of local pollutants and land use activities. The calculation of sub-indices for various parameters facilitated the identification of critical pollutants, with COD and TSS emerging as the primary concerns. Based on the Water Quality Index (WQI) calculations, Kampung Hulu Kuala Pansoon was classified as Class II (88.01), while Pekan Bt 18 and Nanding were classified as Class III, with values of 76.50 and 71.68, respectively. This degradation correlates with increasing population density and development activities along the river. The non-point source pollution from human activities is contributing significantly to this decline. To maintain the Langat River as a reliable source of raw water, it should meet Class IIA standards, underscoring the need for improved water management and pollution control measures. The study also analysed trace metal concentrations, detecting all measured metals of As, Cr, Cd, Pb, Al, Zn, and Mn in the downstream area. While most metal levels remained below the National Water Quality Standard (NWQS) limits, Al (0.071 mg/l) exceeded the permissible limit, while Mn (0.09 mg/l) was detected to be close to the allowable threshold. The limitation of time and with the small dataset (3 samples for each sampling point), the calculated WQI in wet season is not a decent representative of the actual trend of WQI along Langat River. Nonetheless, it provides some additional information in supporting State authority in mitigating the unhealthy river water classification that is the main surface water resources. For future studies, it is recommended that additional sampling be conducted at more locations along the Langat River, coupled with the inclusion of hydrological data, to establish more reliable water quality trends during the wet season. Comparative analysis of Water Quality Index (WQI) measurements during both the wet and dry seasons is essential to identify the primary land use activities impacting the river's classification. Collaboration with state authorities should be prioritized to mitigate pollution sources and ensure the river consistently meets the Class IIA WQI standard. This is critical for supporting the sustainability goals outlined in the United Nations' SDG 6, which aims to ensure universal access to clean water and sanitation. Continuous monitoring is vital to safeguard the Langat River, a water source for the Selangor State. Consequently, effective local policies, supported by proactive leadership from local governments, are crucial to managing pollution and maintaining water quality across the transboundary Langat River.

ACKNOWLEDGEMENT

The authors are infinitely grateful to the School of Civil Engineering, College of Engineering, Universiti Teknologi MARA, Shah Alam, for financially supporting this study and providing the resources and facilities.

DECLARATION OF COMPETING INTEREST

None.

REFERENCES

Abidin, M.Z., Kutty, A.B., Lihan, T. & Zakaria, N.A. 2018. Hydrological change effects on Sungai Langat water quality. *Sains Malaysiana* 47(7): 1401–1411.

Ahmad, S., Kutty, A.A., Raji, F. & Saimy, I.S. 2015. Water quality classification based on water quality index in Sungai Langat, Selangor, Malaysia. *Jurnal Teknologi* 77(30).

Ahmed, M.F., Mokhtar, M.B. & Majid, N.A. 2021. Household water filtration technology to ensure safe drinking water supply in the Langat River Basin, Malaysia. *Water* 13(8).

Ahmed, M.F., Mokhtar, M.B., Lim, C.K. & Majid, N.A. 2022. Identification of water pollution sources for better Langat River basin management in Malaysia. *Water* 14: 1904.

Alam, L., Mokhtar, M., Alam, M.M., Bari, M.A., Kathijotes, N., Goh, C.T. & Lee, K.E. 2015. Seasonal variation and preliminary risk assessment of trace element pollution in surface water from Langat River, Malaysia. *International Journal of Applied Environmental Sciences* 10(1): 19-40

Ali, A.N.A. & Bolong, N. 2021. Determination of water quality in Universiti Malaysia Sabah (UMS), Kota Kinabalu: The effectiveness of stormwater management systems. *Materials Today: Proceedings* 46: 1848-1854.

Anh, N.T., Nhan, N.T., Schmalz, B. & Le Luu, T. 2023. Influences of key factors on river water quality in urban and rural areas: A review. *Case Studies in Chemical and Environmental Engineering* 100424.

Aris, A.Z., Lim, W.Y. & Looi, L.J. 2015. Natural and anthropogenic determinants of freshwater ecosystem deterioration: An environmental forensic study of the Langat River Basin, Malaysia. *Environmental Management of River Basin Ecosystems:* 455-476. https://doi.org/10.1007/978-3-319-13425-3_21

Basheer, A.O., Hanafiah, M.M. & Abdulhasan, M.J. 2017. A study on water quality from Langat River, Selangor. *Acta Scientifica Malaysia (ASM)* 1(2): 1-4.

Bernama. 2016. Langat, Cheras Water Treatment Plant Shutdown due to Odour Pollution, Selangor Exco Says. *Malaymail Online*, January.

Ching, Y.C., Lee, Y.H. & Toriman, M.E. 2015. Effect of the big flood events on the water quality of the Muar River, Malaysia. *Sustainable Water Resources and Management* 1: 97–110.

DOE. 2023. *National Water Quality Standards for Malaysia.* Putrajaya: Official Portal of Department of Environment. Doe.gov.my. https://www.doe.gov.my/en/national-river-water-quality-standards-and-river-water-quality-index/

DOE. 2015. Malaysia Environmental Quality Report 2015. Putrajaya: Department of Environment.

Hanafiah, M.M., Yussof, M.K.M., Hasan, M., AbdulHasan, M.J. & Toriman, M.E. 2018. Water quality assessment of Tekala River, Selangor, Malaysia. *Applied Ecology and Environmental Research* 16: 5157-5174.

HORIBA. 2013. *Instruction Manual Portable Dissolved Oxygen Meter.* Kyoto: HORIBA Ltd.

Jamal, N.Z.A., Rosli, M.A. & Abdul-Rahman, M.A. 2023. Assessing the river water quality of Sungai Masai, Johor by using water quality index (WQI). *Journal of Advanced Industrial Technology and Application* 4(1): 80-85.

Li, S. & Zhang, Q. 2010. Risk assessment and seasonal variations of dissolved trace elements and heavy metals in the Upper Han River, China. *Journal of Hazardous Materials* 181: 1051-1058.

Liang, Y.Q., Annammala, K.V., Martín, P., Yong, E.L., Mazilamani, L.S. & Najib, M.Z. 2020. Assessment of physical-chemical water quality characteristics and heavy metals content of lower Johor River, Malaysia. *Journal of Environmental Treatment Techniques* 8(3): 961-966.

Lim, W.Y., Aris, A.Z., Ismail, T.H. & Zakaria, M. 2013. Elemental hydrochemistry assessment on its variation and quality status in Langat River, Western Peninsular Malaysia. *Environmental Earth Sciences* 70(3): 993–1004.

McInerney, P.J., Giling, D.P., Wolfenden, B. & Sengupta, A. 2023. A synthesis of floodplain aquatic ecosystem metabolism and carbon flux using causal criteria analysis. *Limnology and Oceanography* 68: 97–109.

Olıas, M., Nieto, J., Sarmiento, A., Cerón, J. & Cánovas, C. 2004. Seasonal water quality variations in a river affected by acid mine drainage: The Odiel River (South West Spain). *Science of the Total Environment* 333: 267-281.

Pairan, M.A., Zamri, N. & Ismail, A. 2023. Assessment of water in Terengganu River, Malaysia using multivariate statistical techniques and fuzzy DEMATEL. *International Journal on Advanced Science, Engineering and Information Technology* 13(4): 1225-1234.

Shaghaghi, N., Fazlollahi, F., Shrivastav, T., Graham, A., Mayer, J., Liu, B., Jiang, G., Govindaraju, N., Garg, S., Dunigan, K. & Ferguson, P. 2024. DOxy: A dissolved oxygen monitoring system. *Sensors* 24: 3253.

Sinurat, M.A.P., Utomo, K.P. & Desmaiani, H. 2024. Pengaruh aktivitas budaya keramba jaring apung terhadap kualitas air Sungai Mempawah. *Jurnal Teknologi Lingkungan Lahan Basah* 12(2): 559–566.

Xu, Y.J., Xu, Z. & Potter, L. 2024. Connectivity of floodplain influences riverine carbon outgassing and dissolved carbon transport. *Science of The Total Environment* 924: 171604.