Malaysian Journal of Chemistry, 2024, Vol. 26(3), 445-455
(Special Issue: *3rd Virtual International Symposium on Sciences 2023*)

Assessment of Water Quality and Heavy Metals Concentration in Selangor River

Nadasofa Mohd Saidi[1]*, Sabarina Md Yunus[2], Nur Aliah Zaizisham[1] and Nik Azlin Nik Ariffin[1]
[1]Faculty of Applied Sciences, Universiti Teknologi Mara (UiTM) 40450 Shah Alam, Selangor, Malaysia
[2]Faculty of Applied Sciences, Universiti Teknologi Mara (UiTM) Cawangan Pahang, Kampus Jengka, Pahang, Malaysia
*Corresponding author (e-mail: nadasofasaidi@gmail.com)

From a practical and strategic point of view, the Selangor River is crucial to Malaysia's water supply. The nature of the principal pollutant sources may change from rural to industrial, causing a wide range of environmental problems and competing priorities among water users. The Water Quality Index (WQI) is a numerical metric used to evaluate and describe the overall quality of water in a given water body such as river, lake, or ocean. It is calculated by taking into account on several physical, chemical, and biological parameters/factors (turbidity, pH, total nitrogen, COD, BOD) that are known to impact the suitability of water for various uses, such as consumption/ drinking, household chores, irrigation, recreation, and aquatic life. This study was conducted to determine the water quality status of Selangor River. Water sampling was conducted at ten (10) different locations during October 2022. Heavy metals such as Nickel (Ni), Lead (Pb), and Zinc (Zn) were analysed using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). This study found that the water quality index of Selangor River was classified as Class III, which was considered slightly polluted according to the classification of WQI. The mean concentrations of Ni, Pb, and Zn in Selangor River were 1.4±0.07 µg/L, 17.50±0.66 µg/L, and 5.67±0.13 µg/L, respectively. Moreover, a positive and robust significant correlation was identified between temperature and COD, BOD5 with TSS, and Ni, as well as between Ni and Ammoniacal Nitrogen (AN). The results of this study could be useful to the authorities and government in carrying out continuous environmental assessments so that our pollution levels can be monitored.

Keywords: Heavy metal; pollution index; ICP-OES; Selangor river; WQI

Received: November 2023; Accepted: February 2024

Naturally, water has been known to be one of the renewable sources for all living things to survive, as it is called basic needs, such as food and water. The river stands out as a primary source, efficiently supplying substantial fresh water for various life forms, including humans and aquatic activities [1, 2]. In Malaysia, Selangor is considered a water-stressed area due to the increase in water demand and limited suitable freshwater resources for treatment and distribution. The tremendous increase in population, urbanization, and industrialization made the rivers in Selangor arguably the most polluted compared to other states [3]. These circumstances lead to a recurring pattern of unscheduled water supply interruptions over the years, adversely affecting a majority of consumers. In a broader context, the Selangor River plays a crucial role as a water supplier since it ultimately feeds into the water reservoir [4, 5]. Nevertheless, with the onset of urbanization, our natural environment has been significantly affected, particularly through the induction of river water pollution due to various human activities, both industrial and domestic. These activities involve the unintentional or intentional release of pollutants such as heavy metals into the river bodies [6, 7]. As tremendous development proceeds along the Selangor River, Kuala Selangor, despite its recreational significance, it is being subjected to a substantial increase in pollution levels. This exerts a pronounced negative impact on the ecosystem, consequently heightening public concerns regarding environmental health as well [8].

Furthermore, to establish a baseline for future reference regarding the water quality status of the Selangor River, an assessment is conducted using the Water Quality Index (WQI). For instance, the National Water Quality Standards for Malaysia (NWQS) employs WQI as a fundamental tool for evaluating water bodies, classifying pollution levels, and determining beneficial uses [9]. This assists entities such as the Department of Environment (DOE) of Malaysia in categorizing the country's rivers. The assessment encompasses the analysis of various factors, including Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH3-N), pH, temperature, and Total Suspended Solids (TSS). The utilization of WQI in Malaysia has received endorsement from the Malaysian Department

†Paper presented at the 3rd Virtual International Symposium on Sciences (3rd VISoS 2023)

of Environment (DOE). It is a set of water quality recommendations that divides water into groups based on water quality for public consumption, such as raw water sources, recreational purposes, irrigation and aquaculture [9].

Thus, this study aims to investigate the water quality of Selangor River in detecting its contamination level through calculating the WQI as well as analysing the concentration of heavy metal (Pb, Ni and Zn) using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) prior proceeding in-situ and ex-situ measurements including other correlated parameters.

EXPERIMENTAL

Samples Collection and Analysis

The study area of the desired river (Latitude: 3° 21' 10" N, Longitude: 101° 15' 20" E) has covered a 500-metered radius of 10 sampling locations located along the Selangor River (Figure 1), mainly to enhance representativeness homogeneity of the samples, as labelled from sampling point 1 (S1) to sampling point (S10). The pre-setting of the operation states as follows: Sample collection; the pre-cleaned high density polyethylene containers were washed three times with running river water, meanwhile, during low tide, 1 liter of river samples were taken and stored in the container. Sample preservation; the water samples were acidified until obtaining pH 2 using concentrated 65% nitric acid (HNO_3) brand EMSURE supplied by Merck Malaysia. Sample preparation; water samples were filtered using vacuum filtered, then diluted with 1% nitric acid. All of the reagents used comes from analytical grade chemicals. 1000 mg/L of analyte was present in a single-element stock standard solution. Analytical standards have been prepared by diluting with 1 percent (v/v) HNO_3 in the range of 0.05 to 1.0 mg/L. Ultrapure water that contains 1% HNO_3 was used to prepare the blanks.

In-Situ Analysis

Acidity (pH), temperature, salinity, total dissolved solids (TDS), and Dissolved Oxygen (DO) were the basic parameters that have been used to determine the quality of the Selangor River. YSI Model Multi probe system were used to provide in-situ measurements of temperature, dissolved oxygen (DO), electrical conductivity, total dissolved solids (TDS), and pH. It was calibrated and cleaned before being used in the sampling. Triplicate samples were collected at each in-situ parameter sampling site. Each water sample was appropriately labelled with the date and location of sampling. Upon receipt of the samples, the laboratory preserved them by adding nitric acid to achieve acidity (pH = 2), which was measured using a pH meter. The use of acid helped prevent the precipitation of metal hydroxides and metal ion adsorption into the container walls. The results of the samples' analysis were recorded. When moving the samples, care was taken to ensure that the device did not come into contact with the sample containers, and preservation measures were implemented on-site immediately after sample collection [10].

Figure 1. Location of sampling points within Selangor River as summarised in Table 1.

Table 1. Sampling locations along the Selangor River.

Sampling Location	Latitude	Longitude	Description of Sampling Location
S1	3.3636161 º	101.2605232º	Estuary
S2	3.3593897º	101.2603275º	Industrial and aquaculture activities
S3	3.3567279º	101.2579921º	Estuary
S4	3.3537614º	101.2583487º	Estuary
S5	3.3503307 º	101.2572468º	Industrial and aquaculture activities
S6	3.3508907º	101.2557767º	Industrial and aquaculture activities
S7	3.3490526º	101.2573356º	Estuary
S8	3.3461929º	101.2577479º	Businesses and industrial activities
S9	3.3449654º	101.2617689º	Estuary
S10	3.3422534º	101.2634106º	Estuary

Ex-Situ Analysis

Laboratory measurements were made of the concentrations of BOD5, COD, TSS, NH3-N, and heavy metals. The water samples were put in a temporary ice box container for transit and then analyzed for BOD5, COD, heavy metals, and NH3-N parameters. Following the steps outlined in Standard Method APHA 5210-B, the biochemical oxygen demand (BOD5) was determined. The reactor and spectrophotometer were utilized to analyze the chemical oxygen demand (COD), with the addition of digestion reagent as a reagent. A spectrophotometer was used to measure the number of suspended solids (SS), ammoniacal nitrogen (NH3-N), and Nessler ammonia reagent, utilizing Mineral Stabilizer, Polyvinyl Alcohol Dispersing Agent, and Nessler Reagent. The pH meter was used to determine the pH. Each parameter was examined, and the river's water quality rating was determined based on Malaysia's National Water Quality Standards [11].

Water Quality Index (WQI) Calculation

The WQI, predominantly utilized in Malaysia, was formulated by an expert board. This board provided guidance on the selection of factors and the weighting of parameters in the index. The six parameters utilised for the WQI are pH, ammoniacal nitrogen (NH3-N), total suspended solid (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD5), chemical oxygen demand (COD), and total suspended solid (TSS). A river may be classified into a variety of groups based on the computed WQI, each of which illustrates the beneficial uses the river may be put to [12]. The categorization is based on the permitted limits for the specified pollutant criteria. The parameters dissolved oxygen (DO), biochemical oxygen demand (BOD5), chemical oxygen demand (COD), total suspended solid (TSS), ammoniacal nitrogen (NH3-N), and pH will be used in accordance with the DOE's WQI equation to ascertain the parameters' values and the Selangor River's overall water quality classification. After the sub-indices are computed, WQI is then will be determined by this equation.

Where,
SIDO = Sub-index for DO; SIBOD = Sub-index for BOD; SICOD = Sub-index for COD; SIAN = Sub-index for AN; SISS = Sub-index for SS; and SIpH = Sub-index for pH.

$$WQI = (0.22 * SIDO) + (0.16 * SICOD) + (0.19 * SIBOD) + (0.16 * SISS) + (0.12 * SIPH) + (0.15 * SIAN)$$

Table 2. Calculation of WQI.

Sub-indices DO (% saturation)	
$x < 8$	SIDO = 0
$x \geq 92$	SIDO = 100
$8 < x < 92$	SIDO = $-0.395 + 0.030^{x2} – 0.00020^{x3}$
Sub-indices BOD (mg/L)	
BOD ≤ 5	SIBOD = 100.4 – 4.23BOD
BOD > 5	SIBOD = 108e-0.055BOD – 0.1BOD
Sub-indices COD (mg/L)	
COD < 5	SICOD = -1.33x + 99.1
COD > 5	SICOD = $103e^{-0.0157x} – 0.04x$
Sub-indices ammonia, AN (mg/L N)	
$x \leq 0.3$	SIAN = 100.5 – 105x
$0.3 < x < 4$	SIAN = $94^{e-0.573x} – 5\|x – 2\|$
$x \geq 4$	SIAN = 0
Sub-indices TSS (mg/L)	
$x \leq 100$	SITSS = $97.5e^{-0.00676x} + 0.05x$
$100 < x < 1000$	SITSS = $71e^{-0.0016x} – 0.015x$
$x \geq 1000$	SITSS = 0
Sub-indices pH	
$x < 5.5$	SIpH = 17.2 – 17.2pH + $5.02x^2$
$5.5 \leq x < 7$	SIpH = -242 + 95.5pH – $6.67x^2$
$7 \leq x < 8.75$	SIpH = -181 + 82.4pH – $6.05x^2$
$x \geq 8.75$	SIpH = 536 – 77.0x + $2.76x^2$

Note: x is the concentration in mg/L for all parameters except pH
Source: Department of Environment, Ministry of Natural Resources and Environment Malaysia (NRE).

Sample Measurement of Heavy Metals

Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) was employed to analyze the collected samples for heavy metal concentrations in the Selangor River. Samples taken on the day of collection underwent prompt analysis for heavy metals to ensure high accuracy in detection outcomes. Concentrations of total dissolved elements and major ions, such as Nickel (Ni), Lead (Pb), and Zinc (Zn), were assessed to evaluate water quality. A standard solution of ICP multi-element was used for analysis, and a standardized combination of heavy metals was prepared for each element to ensure precise detection results, the samples obtained throughout the sampling day were immediately examined for the presence of heavy metals. The results of this evaluation were expressed as micrograms per liter (µg/L).

Statistical Analysis

The pollution level of the river water quality assessment was conducted using calculated WQI based on DOE classified water quality [13]. Meanwhile, in order to correlate this study statistically and practically, Pearson's Correlation has been used.

Heavy Metals Concentration

The formula for determining the concentration of an element in a sample is commonly presented as by the real concentration of heavy metals in ICP-OES analysis equation [14]:

$$\text{Concentration } (\mu g/L) = C \times \frac{v_f}{v} xDF$$

Where:

C is the concentration obtained from the instrument (µg/L)

Vf is the final volume of the sample solution after dilution (mL)

V is the initial volume of the sample solution (mL)

DF is the dilution factor $\frac{v_f}{v}$

Heavy Metals Pollution Index (HPI)

The HPI is a method of assessment that shows the compound influence of individual heavy metal on the total quality of water. HPI is sophisticated in two steps.

The first step involves establishing a rating scale for each selected parameter, assigning appropriate weightage to each. The second step is selecting the pollution parameter based on the index. Evaluation is conducted by comparing the measured values against reference values outlined in the National Water Quality Standards for Malaysia (NWQS) [14]. HPI is calculated by the following equation 1:

$$HPI = \sum QiWi \qquad \text{(Eq. 1)}$$

where Wi is the score weight for each parameter preferred for heavy metal assessment and is directly related to the suggested standard, the highest allowable amount for heavy metals' drinking water (Si). The rating is a value between zero and one. Qi, is the Subindex of the ith parameter and was calculated using equation 2:

$$Q_i = \frac{(Mi - Ii)\times 100}{(Si - Ii)} \qquad \text{(Eq. 2)}$$

where Mi is the measured value of the ith parameter; Ii is the desired maximum value (ideal) of the ith parameter; and Si is the suggested ith parameter standard. The crucial index of pollution is 100. The Si and Ii values have been taken from the Malaysian National Water Quality Standard for the current study. After the completion of the results, the concentration of any pollutant was converted into HPI, and the critical HPI value was 100 for drinking water [14].

RESULTS AND DISCUSSION

Water Quality Results for In-situ Analysis

The outcome of the analysis of water in Selangor River's water quality significantly impacts the physico-chemical parameters of the water column such as temperature, DO, pH, TDS and salinity. Since the sampling had been conducted throughout the day, many factors, including the sampling time, weather conditions, and location, have influenced the steadiness of temperature, leading to inconsistent percentage of DO, biological activities, and other parameters [19-20]. The values of the assessed in-situ water quality parameters are presented in Table 3.

The fluctuation in water temperature can be primarily attributed to weather conditions and the timing of sampling. Water temperature stands out as a crucial factor in the analysis of an aquatic ecosystem. It impacts water quality in various ways, including its influence on the amount of dissolved oxygen. Notably, among the ten (10) sampling points, only one dissolved oxygen (DO) result conforms to the standard acceptable levels defined by the National Water Quality Standards, Malaysia (NWQS).

Table 3. The in-situ data collected at Selangor River.

LOCATION	DO, mg/L	pH	TDS, mg/L	SALINITY, ppt	TEMP, °C
S1	**2.87**	8.55	503.87	0.38	27.30
S2	**2.66**	8.40	466.33	0.33	27.30
S3	**3.85**	8.28	1114.00	0.86	27.20
S4	**1.66**	8.16	2298.83	1.85	27.90
S5	**2.61**	8.39	550.33	0.41	27.30
S6	**2.72**	8.35	377.00	0.28	27.30
S7	**2.58**	8.38	365.95	0.27	27.40
S8	**2.72**	8.19	234.00	0.17	27.30
S9	**2.73**	8.16	1847.97	1.46	27.70
S10	0.07	8.40	485.33	0.36	27.30
MEAN	2.45	8.33	824.36	0.64	27.40
Class V of NWQS, 2006	<1	5-9	>4000	>2	>29

**Bold values indicate greater than National Water Quality Standard for Malaysia limit (NWQS).*

Table 4. The ex-situ data collected at Selangor River.

LOCATION	BOD_5, mg/L	COD, mg/L	TSS, mg/L	NH_3-N mg/L
S1	1.80	36.00	31.70	2.54
S2	2.40	37.00	98.10	1.54
S3	1.70	33.00	59.10	2.44
S4	2.10	32.00	39.70	1.96
S5	1.20	80.00	70.60	2.12
S6	1.70	37.00	130.20	1.33
S7	0.10	43.00	65.60	1.26
S8	0.40	40.00	18.90	1.33
S9	0.20	24.00	53.00	1.88
S10	0.10	31.00	63.60	1.42
MEAN	1.17	39.30	63.05	1.78
Class V of NWQS, 2006	12	100	300	2.7

Water Quality Results for Ex-situ Analysis

Table 4 summarises the results for BOD_5, COD, TSS and NH_3-N of Selangor River.

Aerobically, the BOD5 is the number of litres of oxygen needed to keep organic matter stable as microorganisms play roles through biodegradation. The water is considered contaminated if the BOD5 level is high. Based on the data collected, BOD5 value ranges from 0.1 to 2.4 mg/L, yet the highest BOD5 concentration was recorded at S2, while the lowest is at S7. For the BOD5 and COD parameter assessment, the measured values obtained show that sampling point 2 had recorded as the most polluted river water quality within the industrial and aquaculture activities. The most noticeable finding was that the river water at sampling point 2 was contaminated by high BOD5 and COD value originates from anthropogenic activities near the chosen sampling area. The mean value for BOD5 concentration in Selangor River was 1.17 mg/L. It was found that there was a huge amount of organic waste, such as dead plants, green plants, sewage, food waste, at S2 which recommended that there would be a significant number of biodegrading bacteria and considering may be contributed by nearby activities like restaurants, residential, commercial building, and other associated activities [15]. Municipal and industrial wastewater, agricultural runoff, and other polluting discharges are all assimilated or carried away by rivers. Regarding pollution sources, municipal and industrial wastewater discharges are year-round events that are heavily influenced by the local climate. Based on a study conducted by [4-5], the BOD5 of Semenyih River was in the range from 0.63 to 4.56 mg/L. The DOE water quality index for Malaysia determined that Selangor River was classified as Class II, which required some treatment. However, fewer factors can contribute to microbial activity at sampling points 7, 8, 9 and 10 hence their BOD5 values are lower.

The variation in COD levels between the sampling locations is illustrated in Figure 8. The concentration of COD of Selangor River was range from 24.00 to 80.00 mg/L; S5 has the highest concentration against the lowest value from S9. The mean value of COD in Selangor River was 39.30 mg/L. It showed that Selangor River COD concentration is within the standard allowable limit of NWQS, which is 50 mg/L. As a result of the significant amount of oxygen that is used up during the decomposition of organic matter in the water, the chemical oxygen demand (COD) at S5 was substantially higher than it was at the other locations. As a direct consequence of this, there would have been an extremely low availability of oxygen to support the existence of other aquatic organisms. When it comes from natural sources, water nearly always contains living organisms, which are essential components of the biogeochemical cycles in aquatic environments. It is important to note that some of these can be harmful to humans if they are present in water intended to be consumed by humans, including bacteria, parasitic worms, fungus and viruses. The capacity of aquatic settings to support healthy ecosystems is influenced by the availability of water as well as its physical, chemical, and biological composition. When water quality and quantity are degraded, organisms are negatively impacted, and ecosystem services may be threatened [16]. Based on the DOE classification, the average value of COD analysed in Selangor River was categorized as CLASS III.

NH3-N can be used as an indicator for the nutrient content, organic enrichment, and general water quality of a given body of water. Hence, detected levels of NH3-N over a limit signifying the presence of polluted river water. The evaluation of amount of NH3-N found in the Selangor River has put an outcome with a range from 1.26 to 2.54 mg/L. The highest NH3-N value was recorded at S1, while the lowest was at S7. At S1, it was found that more organic matter was utilized in waste production, resulting in the highest value of NH3-N. However, study by [4] detected a lower range which in between 0.02 mg/L to 0.89 mg/L of NH3-N in Semenyih River. Meanwhile, a higher concentration of NH3-N which range from 3.75 to 8.71 mg/L were found in Selangor River [17]. According to the NWQS, the maximum limit level of NH3-N for Malaysian rivers that support aquatic life is 0.9 mg/L. Nevertheless, the concentration of NH3-N was within this level range and is classified as class II according to the DOE and NWQS. Therefore, there is less NH3-N in household sewage than in ordinary sewage, but if the concentration is too high, it could harm the aquatic quality of the urban stream, which has a low assimilative capacity.

In addition, the particles that are suspended in water are either inorganic or organic. The turbidity of river water is affected by both inorganic and organic particles, with the former contributing to a higher total suspended solids concentration. A higher TSS value means more pollution is being produced in the river. The TSS values of Selangor River ranged from 18.9 to 130.2 milligrams per litre in this present study. Regarding TSS, S3 has the highest readings, while S8 has the lowest. It was determined that S3 was in CLASS III of the DOE Water Quality Index for Malaysia, while S8 was in CLASS I. The mean value of TSS concentration was 63.05 mg/L, classified as CLASS III by DOE water quality index standards. However, the study of Semenyih River by [4] found that lower TSS value ranged from 11.70 to 58.1 mg/L. Meanwhile, a previous study of Selangor River, recorded a range from 1 to 2234 mg/L [18]. Based on the NWQS, the maximum threshold limit of TSS for Malaysian rivers that support aquatic life is 150 mg/L [19]. However, depending on the amount of runoff on the day of sample, the TSS loading result in the river water can be different. The TSS result in river water can be reduced by increasing the runoff level, which is the rainfall rate, because the water will be diluted. Since these particles could include biological material, they also require oxygen.

Water Quality Index

Briefly, calculating the overall WQI for a river basin, the WQI values from each sampling location within that Selangor River basin are averaged together. Based on the assessments (Figure 2), the vast majority of the WQI sampling locations fall into the CLASS III category, whilst just one of the sampling locations falls into the CLASS IV category. The DOE Water Quality Index Classification states that S5 is considered to be slightly polluted because its class of classification falls within the range of 60 to 80, whereas the rest of the sampling points are considered to be in the polluted range because their class of classification falls within the range of 0 to 59. The summary for the WQI class may be found in Table 5. Compared to the Selangor River WQI as recorded [20], it was found that the sampling locations located upstream and mid-stream registered as Classes II and III, while in the Rawang sub-basin the water quality falls in Class IV based on the NWQS for Malaysian rivers which indicated that it was slightly polluted and polluted. Based on the mentioned results, it is important to note that the classification of the Selangor River, which ranges from Class III to Class IV, is determined by the different types of water pollution. Hence, consumers need to take on a greater sense of responsibility to guarantee the nation's water supply safety [21].

Table 5. Guidelines for National Water Quality Standards (NWQS) Class and Use.

Class	Water use
Class I	Conservation of natural environment Water supply I – practically no treatment necessary Fishery I – very sensitive aquatic species
Class IIA	Water supply II – conventional treatment required
Class IIB	Recreational use with body contact
Class III	Water supply III – extensive treatment required Fishery III – common, of economic value and tolerant species livestock drinking
Class IV	Irrigation
Class V	None of the above

**Source : DOE, 2006*

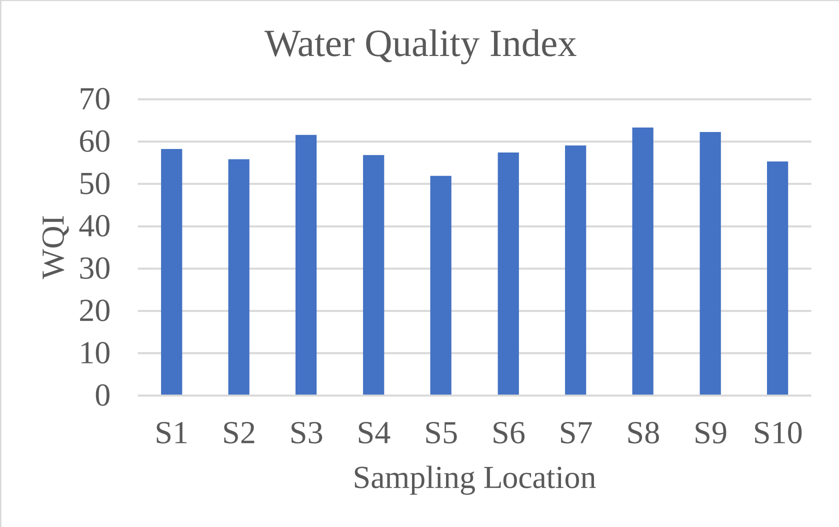

Figure 2. The water quality index results for Selangor River.

Table 6. The total concentration of heavy metals that were found in Selangor River water.

ELEMENT	Heavy metals (µg/L) Lead (Pb)	Nickel (Ni)	Zinc (Zn)
S1	17.00±0.70	NA	6.00±0.30
S2	18.00±0.50	NA	8.00±0.20
S3	17.00±1.10	NA	2.00±0.20
S4	17.00±0.80	NA	4.00±0.10
S5	16.00±0.20	NA	3.00±0.10
S6	20.00±0.12	NA	6.00±0.10
S7	17.00±0.40	7.00±0.50	7.00±0.10
S8	19.00±0.90	7.00±0.20	10.00±0.10
S9	17.00±0.60	NA	5.00±0.10
S10	17.00±1.30	NA	NA
MEAN	17.50	7.00	5.67
RSD (%)	6.73	42.16	44.12
Class V of NWQS, 2006	20	50	400

** NA indicates Not Available*

Quantitative Analysis of Heavy Metal

A total of three heavy metals content comprises lead (Pb), nickel (Ni), and zinc (Zn) were measured at ten sampling locations along the Selangor River in Pasir Penambang. Table 6 shows the total concentration of heavy metals found in river water collected from the coastal area of the Kuala Selangor River, represented by the calculated mean values.

Particularly, this heavy metal concentration has increased in Selangor River due to rapid urbanization and industrialization in the region because the pollution and environmental levels in the research areas can be predicted with the use of the concentration of heavy metals in the water. The standard guideline values for heavy metals have played a big role in ensuring water resources are managed well [22]. The most fundamental physical and chemical characteristics for assessing the quality of river water were given. River water in the Kuala Selangor region was tested, and its levels of heavy metals, including Pb, Ni, and Zn, were observed to discuss the spatial distribution pattern of heavy metals in river water.

Relationship between Water Quality Parameter

Pearson's correlation matrix for element concentrations in river water of Selangor River from the study area is shown in Table 7. Table 7 executes a positive and strong significant correlation between temperature and COD, BOD_5 and TSS, BOD_5, and Ni, as well as between Ni and AN with a value of 0.70, 0.91, 0.84, and 0.79, respectively. Indeed, there is a strong correlation between studied elements, as the components are likely to be derived from the same sources.

Heavy Metal Pollution Index (HPI) in Water

In order to calculate the HPI of the water, the mean concentration value of the selected metals which are Pb, Ni and Zn have been taken into the calculations of HPI with unit weightage (Wi) and standard permissible value (Si) as obtained. All sampling locations in Selangor River show HPI values greater than 100, indicating that these areas were most likely to have high pollution from heavy metals. HPI was found to be the highest in Sampling point 6, which is 139.49 exceeded the critical threshold value of 100. The lowest HPI value found in Sampling Point 5 is 111.60, which also exceeds the HPI value. The temperature, oxygen content, and pH are other physicochemical parameters that can affect heavy metal speciation [23]. The main factor that contributes to high HPI values is the presence of high concentrations of lead water. Pb pollution through the river can be caused by anthropogenic soil activity enrichment. Lead goes through natural weathering processes, and rocks and soils that contain lead can erode over time and release it into rivers [24]. The Selangor River's location near the urban areas with extensive infrastructure, such as roads, buildings, and roofs, which can contribute to lead pollution in rivers, which explains why Sampling Point 6 has the second highest HPI value (139.49). The total concentration of Heavy metals Pollution Index (HPI) in Selangor River water is summarized in Table 8.

Table 7. Pearson correlation analysis between water quality parameters and heavy metals.

	DO	PH	TEMP	SALINITY	TDS	COD	BOD_5	NH_3-N	TSS	Pb	Zn	Ni
DO	1.00											
PH	0.29	1.00										
TEMP	0.09	0.30	1.00									
SALINITY	0.26	0.08	0.02	1.00								
TDS	0.00	0.01	0.03	0.00	1.00							
COD	0.06	0.21	**0.70**	0.02	0.05	1.00						
BOD_5	0.48	0.14	0.04	0.55	0.00	0.03	1.00					
NH_3-N	0.73	0.21	0.06	0.40	0.00	0.05	0.66	1.00				
TSS	0.04	0.13	0.43	0.01	0.08	0.02	**0.91**	0.03	1.00			
Pb	0.14	0.48	0.64	0.04	0.02	0.45	0.07	0.10	0.28	1.00		
Zn	0.43	0.68	0.21	0.11	0.01	0.14	0.21	0.31	0.09	0.32	1.00	
Ni	0.57	0.17	0.05	0.46	0.00	0.04	**0.84**	**0.79**	0.02	0.08	0.25	1.00

0.7-1.0 Strong correlation 0.4-0.7 Moderate correlation 0.2-0.4 Weak correlation <0.2 No correlation

**Bold values indicate Strong correlation*

Table 8. Total concentration of Heavy metals Pollution Index (HPI) in Selangor River water.

Heavy Metals Pollution Index (HPI)										
HEAVY METALS	**SP1**	**SP2**	**SP3**	**SP4**	**SP5**	**SP6**	**SP7**	**SP8**	**SP9**	**SP10**
Lead (Pb)	118.55	125.52	118.55	118.55	111.58	139.47	118.55	132.50	118.55	118.55
Nickel (Ni)	-	-	-	-	-	-	1.84	1.84	-	-
Zinc (Zn)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-
Overall HPI values	118.57	125.54	118.57	118.57	111.60	139.49	120.41	134.36	118.57	118.55

* *HPI values greater than 100, indicates high pollution from heavy metals.*

CONCLUSION

To conclude, the mean value for water quality parameters of Selangor River were determined in this study; DO (2.45 mg/L), pH (8.33), TDS (824.36 mg/L), salinity (0.64 mg/L) and temperature (27.4 ºC). Meanwhile, the mean for COD, BOD5, TSS NH3-N were 39.3 mg/L, 1.17 mg/L, 63.05 mg/L and 1.78 mg/L, respectively. From the findings, the water quality status of Selangor River is classified as Class III, which was considered slightly polluted according to DOE's WQI classification. Also, the average concentration of Ni, Pb, and Zn in Selangor River were 1.4±0.07 µg/L, 17.50±0.66 µg/L, and 5.67±0.13 µg/L, respectively, yet executes a descending heavy metal concentration as follows: Pb > Zn > Ni. Furthermore, there were positive and strong significant correlations found between temperature and COD, BOD5 and TSS, BOD5 and Ni, as well as between Ni and AN with a value of 0.70, 0.91, 0.84, and 0.79, respectively, below NWQS. From the HPI calculations, we can summarize that all sampling locations in Selangor River show HPI values greater than 100, indicating that this Selangor River were most likely to have high pollution from heavy metals (Pb, Ni, and Zn). Measurements of heavy metal concentrations in river water are essential for estimating the environmental and contaminant loads in the research areas. In short, it can be clearly concluded that it is important to understand the water quality parameters and the concentrations of heavy metal in river water. Water quality monitoring is crucial for better regulations on chemical disposal procedures and helps set the baseline information for environmental health to improve a healthier ecosystem.

ACKNOWLEDGEMENTS

The authors acknowledge UiTM Shah Alam for providing all research facilities. Special thanks to Faculty Applied of Sciences members for their help, support, and cooperation in this research work and ICP-OES analysis. Appreciation to Mr. Mohd Syazali, Miss Nurul Huda and Lembaga Urus Air Selangor members for their assistance, collaboration, and support in this study. The authors also acknowledge everyone who is involved directly or indirectly into this project.

REFERENCES

1. Balakrishnan, A. & Ramu, A. (2016) Evaluation of heavy metal pollution index (HPI) of ground water in and around the coastal area of gulf of mannar biosphere and palk strait. *Journal of Advanced Chemical Sciences*, **2(3)**, 331–333.

2. Akhtar, M. N., Anees, M. T., Ansari, E., Ja'afar, J. B., Danish, M. & Bakar, E. A. (2022) Baseline Assessment of Heavy Metal Pollution during COVID-19 near River Mouth of Kerian River, Malaysia. *Sustainability (Switzerland)*, **14(7)**. https://doi.org/10.3390/su14073976.

3. Al-Badaii, F., Abdul Halim, A. & Shuhaimi-Othman, M. (2016) Evaluation of dissolved heavy metals in water of the Sungai Semenyih (Peninsular Malaysia) using environmetric methods. *Sains Malaysiana*, **45(6)**, 841–852.

4. Al-Badaii, F., Shuhaimi-Othman, M. & Gasim, M. B. (2013) Water quality assessment of the Semenyih river. *Journal of Chemistry*, **3216,** 112–122.

5. Al-Badaii, F. & Shuhaimi-Othman, M. (2014) Water pollution and its impact on the prevalence of antibiotic-resistant E. coli and total coliform bacteria: A study of the Semenyih river, peninsular malaysia. *Water Quality Exposure and Health*, **7**, 319-330. https://doi.org/10.1007/s12403-014-0151-5.

6. Al-Sabahi, Esmail & Samsudin, Abdul & Yaacob, Wan Zuhairi & Yacob, W. Z. & Al-Nozaily, Fadhl & Alshaebi, Fares (2009) A Study of Surface Water and Groundwater Pollution in Ibb City, Yemen. *Electronic Journal of Geotechnical Engineering*, **14**.

7. Azha, S. F., Sidek, L. M., Ahmad, Z., Zhang, J., Basri, H., Zawawi, M. H., Noh, N. M. & Ahmed, A. N. (2023) Enhancing river health monitoring: Developing a reliable predictive model and mitigation plan. *Ecological Indicators*, **156**, 111190. https://doi.org/10.1016/j.ecolind.2023.111190.

8. Baharudin, F., Kassim, J., Imran, S. N. M. & Wahab, M. A. (2021) Water quality index (WQI) classification of rivers in agriculture and aquaculture catchments. *IOP Conference Series: Earth and Environmental Scienc*e, **646(1)**, 012023. https://doi.org/10.1088/1755-1315/646/1/012023.

9. Department of Environment (2006) Water Quality Index, Kuala Lumpur, Malaysia.

10. Department of Environment (2009) Malaysia Environmental Quality Report. *Science*, **169(3946)**, 661–661. https://doi.org/10.1126/science.169.3946.661.

11. Elsaid, K., Olabi, V., Sayed, E. T., Wilberforce, T., Abdelkareem, M. A. (2021) Effects of COVID-19 on the environment: An overview on air, water, wastewater, and solid waste. *Journal of Environment Management*, **292**, 112694. https://doi.org/10.1016%2Fj.jenvman.2021.112694.

12. Hasib, N. A. & Othman, Z. (2020) Assessing the relationship between pollution sources and water quality parameters of sungai langat basin using association rule mining. *Sains Malaysiana*, **49(10)**, 2345–2358. https://doi.org/10.17576/jsm-2020-4910-02.

13. Hema, S. & Subramani, T. (2013) Study of physico-chemical characteristics of surface water using regression analysis of Cauvery River and its tributaries in Tamilnadu, India. *Asian Journal of Chemistry*, **25(6)**, 3199-3203.

14. Md Yunus, S., Hamzah, Z., Wood, A. K. & Ahmad, A. (2015) Assessment of heavy metals in seawater and fish tissues at Pulau Indah, Selangor, Malaysia. In *AIP Conference Proceedings*, **1659(1)**, April 2015. https://doi.org/10.1063/1.4916877.

15. Razak, M. R., Aris, A. Z., Zakaria, N. A. C., Wee, S. Y. & Ismail, N. A. H. (2021) Accumulation and risk assessment of heavy metals employing species sensitivity distributions in Linggi River, Negeri Sembilan, Malaysia. *Ecotoxicology and Environmental Safety*, **211**, 111905. https://doi.org/10.1016/j.ecoenv.2021.111905.

16. Arshad, N., Rahman, A. T. A., Jafar, S. M., Aziz, N. W. & Osman, R. (2022) Assessment of water quality in the Temenggor Forest Reserve based on physicochemical data and elemental content. *Malaysian Journal of Chemistry*, **24(2)**, 1–11.

17. Nadmitov, B., Hong, S., In Kang, S., Chu, J. M., Gomboev, B., Janchivdorj, L., Lee, C. H. & Khim, J. S. (2015) Large-scale monitoring and assessment of metal contamination in surface water of the Selenga River Basin (2007–2009). *Environmental Science and Pollution Research*, **22(4)**, 2856–2867.

18. Noraini, R., Seca, G., Johan, I. & Mohd, I. J. (2010) Comparative study of water quality at different peat swamp forest of Batang Igan, Sibu Sarawak. *American Journal of Environmental Sciences*, **6(5)**, 416–421.

19. Othman, F., Uddin Chowdhury, M. S., Wan Jaafar, W. Z., Mohammad Faresh, E. M. & Shirazi, S. M. (2018) Assessing risk and sources of heavy metals in a tropical river basin: A case study of the Selangor River, Malaysia. *Polish Journal of Environmental Studies*, **27(4)**, 1659–1671.

20. Rahim, A. H. A. & Kasmuri, N. (2020) Assessment of water quality index and heavy metals in Sungai Bunus, Malaysia. *Journal of Physics: Conference Series*, **1529(2)**, 022028. https://doi.org/10.1088/1742-6596/1529/2/022028.

21. Ruslan, N. I., Abbas, A. R., Salleh, M. S., Alias, M. & Rahim, N. (2022) Future outlook of fresh water supply and demand in Selangor. *IOP Conference Series: Earth and Environmental Science*, **1102(1)**, 012044. https://doi.org/10.1088/1755-1315/1102/1/012044.

22. Shuhaimi-Othman, M., Lim, E. C. & Mushrifah, I. (2007) Water quality changes in Chini Lake, Pahang, west Malaysia. *Environmental Monitoring and Assessment*, **131**(1-3), 279-92 (Aug. 2007). doi: 10.1007/s10661-006-9475-3.

23. Tengku Ibrahim, Tengku Nilam & Othman, Faridah & Mahmood, Noor (2020) Baseline Study of Heavy Metal Pollution in a Tropical River in a Developing Country. *Sains Malaysiana*, **49**, 729-742. doi: 10.17576/jsm-2020-4904-02.

24. Waziri, M. & Ogugbuaja, V. O. (2010) Inter-relationships between physicochemical water pollution indicators: A case study of River Yobe-Nigeria. *American Journal of Scientific and Industrial Research*, **1(1)**, 76–80.