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ASSESSMENT OF THE CURRENT SPATIAL-TEMPORAL VARIATIONS OF TOTAL DISSOLVED SOLIDS ON THE SURFACE WATERS OF KUALA PERLIS, PERLIS

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Abstract

Total dissolved solids (TDS) have a terrible impact on river water quality. The issues were compounded further by the health risks posed to residents and the uproar generated by elevated levels of total dissolved solids in the water bodies. This study aims to evaluate the spatial-temporal fluctuations of total solid content, namely total dissolved solids (TDS), on the surface water of Kuala Perlis, Perlis. In December 2021, the sampling sites were established and recorded using Global Positioning Systems (GPS). Five sampling locations were selected for each morning, afternoon, and evening session and water samples were collected and transported into the laboratory. The total dissolved solids were studied using gravimetric analysis and the American Public Health Assessment (APHA) standard. The analysis of variance (ANOVA) was set at 0.05 to determine the significant difference between the spatial-temporal mean readings of TDS using the Statistical Package for the Social Sciences (SPSS) version 26. The TDS ranges were 195.00 mg/L to 4900.00 mg/L, 325.00 mg/L to 9400.00 mg/L, and 296.00 mg/L to 8500.00 mg/L, respectively, for the morning (AM), afternoon (AF), and evening (PM) sampling times throughout five sampling stations. The research found a significant difference in the mean TDS readings concerning spatial variations ($p > .05$). However, there is no significant difference concerning temporal variations of TDS ($p < .05$) on the surface waters of Sungai Kuala Perlis. The spatiotemporal findings point to spatial heterogeneity in TDS measurement across sampling station 1, sampling station 2, and sampling station 5 and but not at any different time in Kuala Perlis. The impact of total dissolved solids concentration on living, environment, and riverine infrastructures was also adequately explored. The researcher, the government, and non-governmental organizations can use the preliminary TDS fluctuation data to prepare for the Kuala Perlis region's future social and economic growth by monitoring river health or measuring pollution. The information could also help to improve ecologically friendly river management and protect the Sungai Kuala Perlis ecosystem.

Keywords: Estuary, Kuala Perlis, Spatiotemporal Study, Total Dissolved Solids, Water Quality Monitoring

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Introduction

River bodies have been one of the significant interesting research subjects to be extensively studied over the latest few decades due to their importance. River streams benefit and support the ecosystem by improving water quality, promoting biodiversity, protecting vulnerable species, and providing protein sources for low-income households, and even river sediment could assist soil fertility in crop production irrigated by river water (Dugan et al., 2006; Jordan & Fairfax, 2022; Kaletova et al., 2022; Kamaruddin et al., 2018, Kamaruddin et al., 2020). Local authorities took action to preserve the river's health by strategizing and developing a firm river monitoring protocol to minimize water pollution in facing the depletion of freshwater issues and also utilizing various techniques (Department of Environment, 2020; Kamaruddin et al., 2019; Kamaruddin et al., 2022). The water quality index (WQI), which consists of six parameters, was used to analyze water bodies in Malaysia. These parameters are ammoniacal nitrogen (AN), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), pH, and suspended particles (SS) (Department of Environment Malaysia, 2017; Wong et al., 2021). Despite the measures taken to monitor the river's health, river health monitoring is limited by the dynamics and variability of water bodies that frequently change over time and places.

Water quality varies throughout time and space due to changes in anthropogenic or natural factors. As a result, finding pollution sources is complicated and time-consuming. Due to Malaysia's tropical climate, seasonal monsoons substantially impact the river quality, with the increased occurrence of extreme precipitation events (Kamaruddin et al., 2021; Wong et al., 2021). It has been conclusively shown that anthropogenic sources are the primary pollution sources in places with moderate to high pollution levels (landfill, industrial activities, and sewage discharge). In contrast, agricultural runoff is the primary cause of pollution in low-pollution areas (Hashim et al., 2022; Tengku Ibrahim et al., 2021). Pollution was not the sole cause of physicochemical river water quality; river ecosystems also significantly determined water quality (Aweng et al., 2021). Sheldon and Fellows (2010) have proposed the role of flow on water quality. Water quality varied spatially and temporally; the most extensive spatial variability occurred during the no-flow phase, with flow-driving temporal changes. In order, to ensure a good and ideal ecosystem, water quality monitoring and other activities that describe environmental monitoring should be pursued (Kamaruddin et al., 2022). These findings suggest that variability in water quality is permittable spatiotemporally. Nevertheless, the variation of physicochemical parameters that could cause an impact on human health and the environment, such as total dissolved solids, should be properly comprehended.

Total dissolved solids (TDS) bring forth appalling impacts on the water quality of river bodies. The situations were exacerbated more due to health hazards imposed on living and commotion caused by elevated levels of total dissolved solids in the water bodies. Total dissolved solids are a portion of solids such as calcium, chloride, nitrate, phosphorus, iron, sulphur, and other ions that pass through a filter with a nominal pore size of 2.0 microns (or smaller) under defined conditions (American Public Health Association, 1999). Waters with high dissolved solids have poor palatability and may cause an adverse physiological reaction in the temporary consumer (American Public Health Association, 1999). Many types of aquatic life are harmed when TDS levels are high, especially when dissolved salts are present, as the salts dehydrate animal skin (Bhateria & Jain, 2016). TDS ranges from 0 to 1000 mg/L in freshwater, 1000 to 10000 mg/L in brackish water, and 10000 to 100000 mg/L in saline water (Sylus & Ramesh, 2015). Even though the adverse impact of TDS is significant for the aquatic organism compared to humans, a current assessment of the spatiotemporal variation of TDS should be conducted to preserve sensitive marine species, especially in an area such as Sungai Kuala Perlis.

Previous studies showed background and prevalence findings on the water quality monitoring conducted in Sungai Kuala Perlis. Sungai Kuala Perlis has become the principal transit, fishing, and irrigation route for Perlis residents, and its current state has changed over time (Hashim et al., 2022). Sungai Perlis is in northern Peninsular Malaysia, with a latitude of 6.40° and a longitude of 100.13°. The Perlis River has more than ten tributaries and a basin area of approximately 350 km^2 (Amneera et al., 2013). In 2006, Sungai Perlis was categorized as Class III with a WQI score of 68, which is slightly polluted. In 2019, Sungai Perlis becomes better but is still within Class III, with scores of 76-91, mildly contaminated in Sungai Serai. Fortunately, in 2020, Perlis River recovered, ranged WQI scores from 82 to 94, and was classified as clean (Class I and Class II) (Department of Environment, 2020; Department of Environment, 2006). Che Ali et al. (2020) reported that the development of new residential areas and human activities in the vicinity of Sungai Perlis had disrupted the soil surface, resulting in river pollution. Rapid urbanization and other activities in the advanced area may cause erosion, increased runoff, and mass silt flows into the river via sewage discharge. The investigations mentioned above show that numerous research has been conducted to study the water quality index and source points of pollution in Sungai Kuala Perlis. However, no attempt was made to investigate the current spatiotemporal variation of total dissolved solids of surface water in Sungai Kuala Perlis.

Spatiotemporal variation of total dissolved solids in Sungai Kuala Perlis should be investigated to determine the current state, recent river health assessment, and potability of the available water sources. Water chemistry in rivers and streams varies spatially and temporally and exhibits considerable variety at different geographical scales (Fatema et al., 2015). Surface waters can be affected by non-point source pollution caused by surface and subsurface runoff from croplands and urban areas, which is seasonal and highly influenced by climate variability (Samsudin et al., 2011). Unwanted changes in water's physical, chemical, and biological properties pose a significant hazard to aquatic organisms; thus, it is critical to understand the physicochemical qualities of water parameters and their behaviors to ensure the marine ecosystem's survival (Afsharian et al., 2022). Therefore, this study aims to experimentally investigate and provide preliminary data on the current spatiotemporal total dissolved solids in Sungai Kuala Perlis, Perlis. Overall, it is crucial to monitor the river condition over time so that issues of the potability and depletion of the freshwater sources can be properly brought under control.

Methods

This section summarised the sampling procedure, sampling stations selection, and gravimetric analysis of total dissolved solids (TDS). The observations made during sampling activities were documented to identify potential anthropogenic activities impacting water quality and total dissolved solids.

Sampling Method

Sampling was conducted along Sungai Kuala Perlis, starting from Jetty Tok Kuning (SS1) and continuing to the river's mouth at the fifth location (SS5) in early December 2021. Each sampling site was carefully documented and logged using GPS. Samples were collected in the morning (AM), afternoon (AF), and evening (PM), around one meter below the water surface. Zonation and random sampling method was done based on possible point of pollution. During each sampling, observations were made of the natural landscape and potential anthropogenic components that could affect water quality and total dissolved solids distribution. The collected water samples were labeled according to sampling stations and sent to the laboratory for analysis in 1.5-liter plastic bottles. Figure 1 illustrates the TDS assessment procedures employed in Sungai Kuala Perlis.

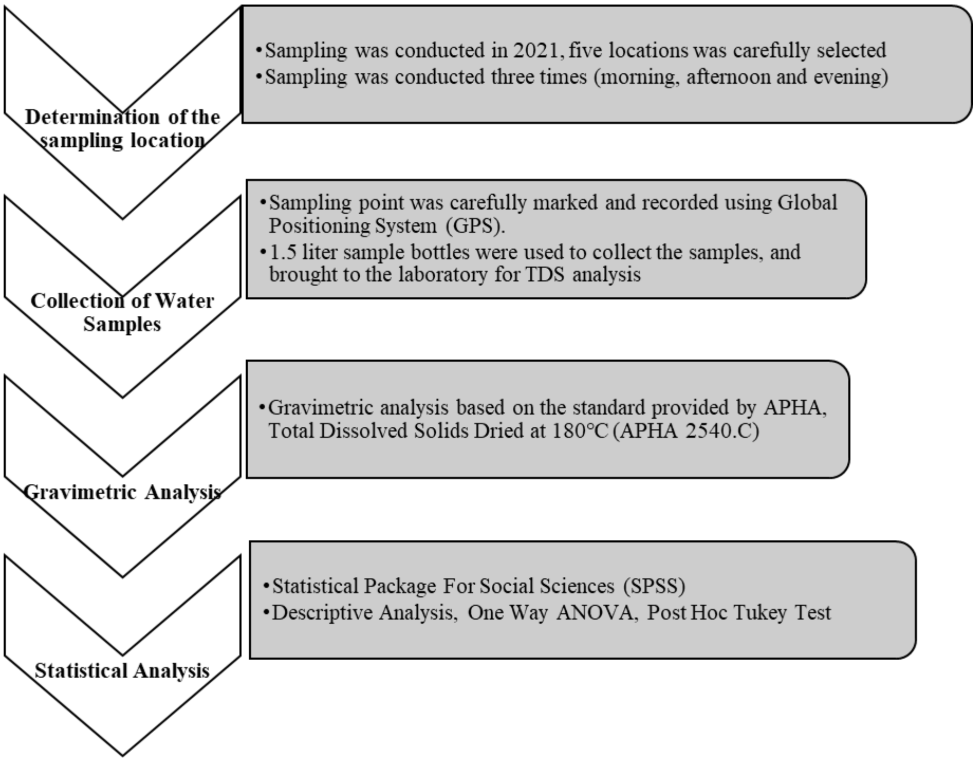

Figure 1: Procedures of TDS Assessment in Sungai Kuala Perlis

Sampling Station Selection

The sampling stations were visited three times: in the morning (AM), afternoon (AF), and evening (PM). Each sample station (SS1-SS5) will be identified during surface water sampling, and the latitude and longitude will be recorded using a GPS. Table 1 shows the sampling station information along with anthropogenic potential in Sungai Kuala Perlis.

Table 1. Sampling Stations Information

Sampling	Location	Coordinate	Anthropogenic Potential
Morning (AM)	SS1	6˚25'04.853"N 100˚09'01.853"E	Agriculture, Jetty Tok Kuning
	SS2	6˚25'19.128"N 100˚08'32.333"E	Agriculture, Fishing Pond
	SS3	6˚25'03.461"N 100˚08'22.434"E	Solar Power Plant
	SS4	6˚24'37.799"N 100˚08'23.903"E	Solar Power Plant, Roadside, Housing Area
	SS5	6˚24'28.511"N 100˚08'23.364"E	Restaurant, Floating Village
Afternoon (AF)	SS1	6˚25'04.992"N 100˚09'00.774"E	Jetty Tok Kuning, Agriculture
	SS2	6˚25'17.364"N 100˚08'46.409"E	Agriculture,Fishing Pond
	SS3	6˚25'20.808"N 100˚08'31.746"E	Fish Pond, Solar Power Plant, Roadside
	SS4	6˚24'57.449"N 100˚08'18.917"E	Roadside, Restaurant
	SS5	6˚24'27.263"N 100˚08'20.742"E	Floating Village
Evening (PM)	SS1	6˚25'04.787"N 100˚09'01.290"E	Jetty Tok Kuning,Agriculture
	SS2	6˚25'22.188"N 100˚08'44.322"E	Agriculture, Fishing Pond
	SS3	6˚25'00.653"N 100˚08'19.679"E	Aquaculture, Solar Power Plant
	SS4	6˚24'34.355"N 100˚08'29.033"E	Solar Power Plant, Roadside, Housing Area
	SS5	6˚24'27.479"N 100˚08'23.364"E	Restaurant, Floating Village

Additionally, Sungai Kuala Perlis sampling stations were plotted based on latitude and longitude for each sampling time to retrieve surface water for sample collection. The map enables the accurate placement of sampling stations. It allows for a complete investigation of potential anthropogenic activities or natural factors affecting the TDS distribution along Sungai Kuala Perlis. Figure 2 (Google Earth, 2022b) shows the sampling stations for morning (AM) sampling; Figure 3 (Google Earth, 2022a) shows the sampling stations for the afternoon (AF) sampling, and Figure 4 (Google Earth, 2022c) showed the sampling stations for the evening (PM) sampling.

Figure 2. Morning Sampling Stations (Google Earth, 2022b)

Figure 3. Afternoon Sampling Stations (Google Earth, 2022a)

Figure 4. Evening Sampling Stations (Google Earth, 2022c)

Gravimetric Analysis of Total Dissolved Solids
Gravimetric analyses were conducted based on the APHA, Total Dissolved Solids Dried at 180℃ (APHA 2540. C) standard procedures to assess TDS content (American Public Health Association, 1999). The filtrate from a well-mixed sample was evaporated to dryness in a weighted plate and dried to a constant weight at 180°C. The total dissolved solids were represented as an increase in dish weight; the rise in dish weight meant the total dissolved solids. Each sampling station's (SS) sample water was analyzed in three batches during the sampling period: morning sampling (AM), afternoon sampling (AF), and evening sampling (PM).

Determination of Total Dissolved Solids
The filtering apparatus was assembled, and a 27 mm diameter, 0.45-micron-porous size filter was used for the analysis. The filter was first seated with a small amount of reagent-grade or distilled water. 300 mL of the sample represented each sampling station. If possible, larger particles were sheared with a magnetic stirrer to obtain a more uniform (ideally homogeneous) particle size. 300 mL of the sample were pipetted into the receiving flask while stirring, and suction was started. The filter was washed with three successive 10-mL volumes of reagent-grade water, allowing for complete drainage between washings, and suction was continued for about 3 minutes after filtration was complete. Samples with high dissolved solids may have required additional washings. The filtrate was divided into 100-mL portions, yielding three replicates for each sampling station. The filtrate was dried in an oven at 180°C, then cooled in a desiccator to balance the temperature before being weighed. Drying, cooling, desiccating, and weighing were continued until a constant weight was obtained, or the weight change was less than 4% of the previous weight or 0.5 mg, whichever was less. 10% of all samples were examined in duplicate. The weight of the evaporating dish/beaker, the weight of the evaporating dish + residue, and the residue were recorded, and the TDS value was calculated. Figure 5 shows the evaporating dish/beaker retaining the TDS before drying (a) and the residue (TDS) retained after drying (b).

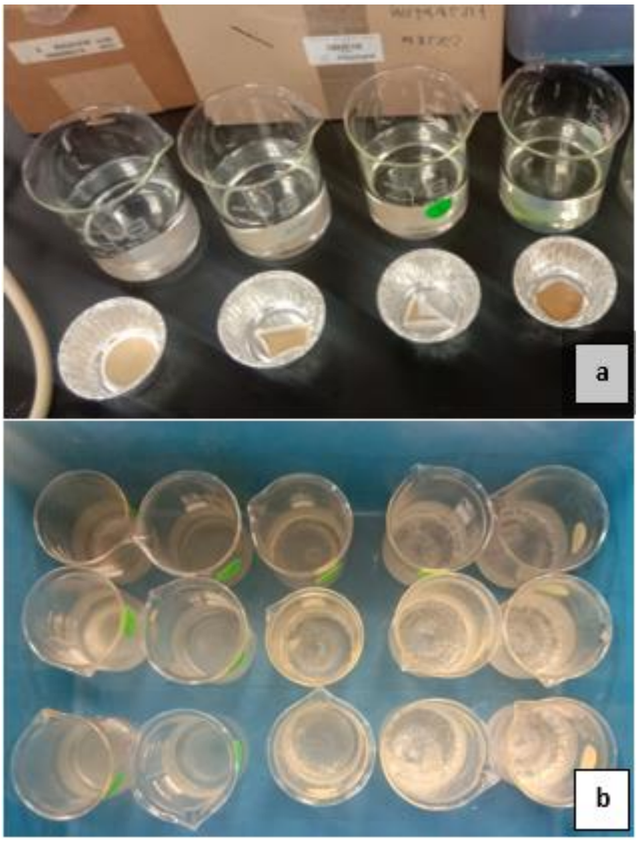

Figure 5. Beaker holding filtered water before drying (a) Residue (TDS) after the oven-dried process(b)

Calculation of TDS

The concentration of TDS was reported as mg/L or as mg/L TDS.

$$\text{TDS mg/L} = \frac{(A - B) \times 1000}{\text{sample volume, mL}} \quad 1)$$

Where:
A = weight of evaporating dish/beaker + dried residue, mg
B = weight of evaporating dish/beaker, mg

Result and Discussion

All the results obtained from the spatiotemporal finding for TDS variation in Sungai Kuala Perlis were discussed separately for temporal and spatial variation of TDS in Sungai Kuala Perlis. The information was tabulated and illustrated in tables and figures. The Statistical Package for the Social Sciences (SPSS) version 26 was used to analyze the data. The current TDS spatiotemporal variation and the impact of TDS on living and the environment were discussed further. Table 2 shows the TDS distribution along Sungai Kuala Perlis.

Table 2. TDS Distribution along Sungai Kuala Perlis

Sampling	Location	TDS (mg/L)
AM	SS1	476
	SS2	195
	SS3	277
	SS4	1898
	SS5	4900
AF	SS1	325
	SS2	1969
	SS3	5760
	SS4	8950
	SS5	9400
PM	SS1	296
	SS2	834
	SS3	4633
	SS4	7650
	SS5	8500

Spatiotemporal Variation of TDS

The results show that the highest value of TDS was recorded during afternoon sampling at the SS5 compared to other sampling stations within three sampling times. Furthermore, it also appears from the data collection that the lowest value of TDS was also recorded at the SS2 during the morning sample collection. Overall, TDS ranges were 195.00 mg/L to 4900.00 mg/L, 325.00 mg/L to 9400.00 mg/L, and 296.00 mg/L to 8500.00 mg/L, respectively, for the morning (AM), afternoon (AF), and evening (PM) sampling times throughout five sampling stations. Generally, the TDS concentration in Sungai Kuala Perlis increases as it approaches the sea compared to inshore based on the positioning of the sampling stations. From the plotted graph, it is apparent that the range of TDS content is lower during the morning sampling compared to other sampling times. Therefore, the research suggests that spatiotemporal variation of TDS on surface waters exists along Sungai Kuala Perlis, Perlis. Figure 6 shows the spatiotemporal variation of TDS in Sungai Kuala Perlis. To comprehend the pattern of changes and ascertain the current spatiotemporal variation of TDS on the surface waters of Sungai Kuala Perlis, spatial and temporal variation of TDS along Sungai Kuala Perlis was thoroughly examined.

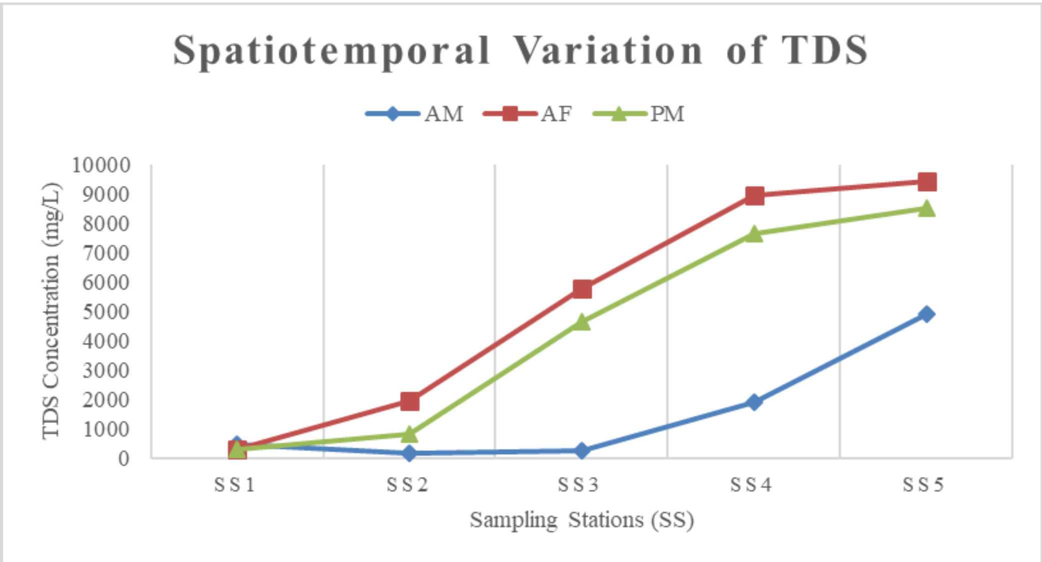

Figure 6: Spatiotemporal Variation of TDS in Sungai Kuala Perlis

Spatial Variation of TDS in Sungai Kuala Perlis

The distribution of the total dissolved solids was examined spatially. The results showed that the mean distribution of TDS at five distinct places ranged from SS1 to SS5 at 365.67 mg/L ±96.65, 999.33 mg/L ±898.48, 3556.67 mg/L ±2985.63, 6166.00 mg/L ±3752.91, and 7600.00 mg/L ±2381.18. SS5 (near the sea) for each sampling had the highest mean TDS observed. In contrast, the first sampling station (SS1) near the jetty (inshore) showed the lowest mean of TDS. A strong correlation, $R^2 = 0.9708$, was found between the sampling station and the mean value of TDS at different sampling stations in Sungai Kuala Perlis. Figure 7 shows the spatial variation of TDS along Sungai Kuala Perlis surface waters. The plotted graph below provides clues on the spatial variations of TDS in Sungai Kuala Perlis, indicating the influence of sampling station and TDS concentrations. A one-way ANOVA test was conducted to prove the hypothesis deduced.

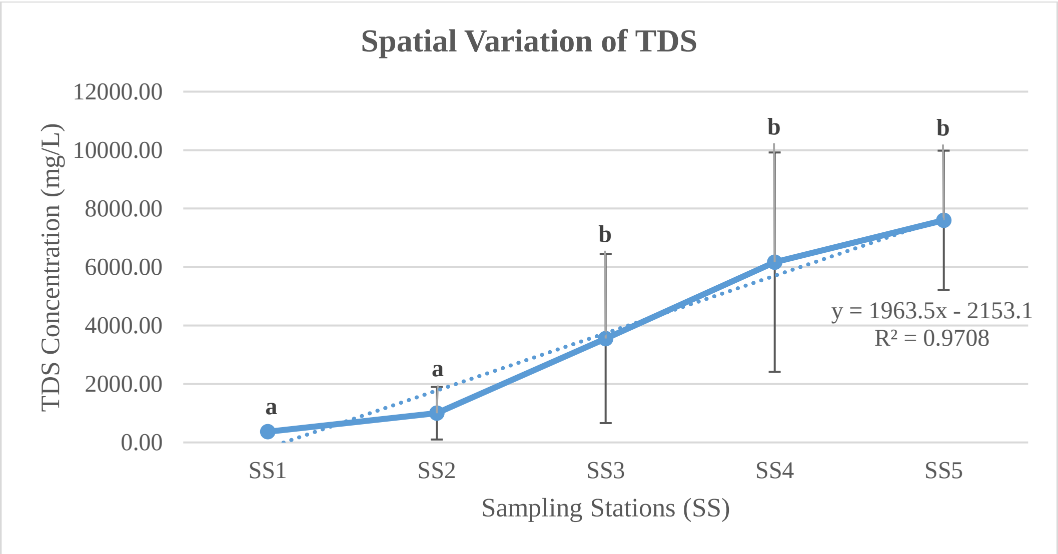

Figure 7: Spatial Variation of TDS in Sungai Kuala Perlis

The effect of the sampling stations (SS1-SS5) on the TDS value of the surface water in Sungai Kuala Perlis was examined using a one-way between-subject ANOVA. As shown in Table 3, there was evidence of a significant effect of the sampling site on the TDS value of surface water along Sungai Kuala Perlis at the $p < .05$ level for the five selected sampling stations [$F(4,10) = 5.144$, $p = 0.016$]. These results suggest that the sampling station changes the TDS value of the water's surface. Thus, the TDS value in Sungai Kuala Perlis is spatially distributed in the study area of Sungai Kuala Perlis. Post hoc Tukey HSD was further conducted to adequately comprehend which sampling site differed from others in detail.

Table 3. One-Way ANOVA for Spatial Variation of TDS Assessment

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		119148107.733	4	29787026.933	5.144	.016
	Linear Term	Contrast	115663894.533	1	115663894.533	19.973	.001
		Deviation	3484213.200	3	1161404.400	.201	.894
Within Groups			57911342.000	10	5791134.200		
Total			177059449.733	14			

The Post hoc comparisons using the Tukey HSD test indicated that the mean score for SS5 (M = 7600.00, SD = 2381.18) was significantly different from SS1 (M = 365.67, SD = 96.65) and SS2 (M = 999.33, SD = 898.48). However, with other locations, which were SS3 (M = 3556.67, SD = 2895.63), and SS4 (M = 6166.00, SD = 3752.91), are not significantly different. To summarise, these findings point to spatial heterogeneity in TDS measurement across sampling station 1, sampling station 2, and sampling station 5. However, there is no spatial variation in the TDS value of the surface water at sampling station 3 or sampling station 4. Table 5 compares the P-value (Tukey Test) of the TDS reading on each sampling station.

Table 4: Comparison of The P-value (Tukey Test) of The TDS Reading on Each Sampling Station

Comparison Between Sampling Stations (SS)		**P-value**
SS1	SS2	.997
	SS3	.516
	SS4	.084
	SS5	***.027**
SS2	SS1	.997
	SS3	.696
	SS4	.138
	SS5	***.045**
SS3	SS1	.516
	SS2	.696
	SS4	.682
	SS5	.308
SS4	SS1	.084
	SS2	.138
	SS3	.682
	SS5	.945
SS5	SS1	***.027**
	SS2	***.045**
	SS3	.308
	SS4	.945

The mean is significantly different at 0.05 level ($p<0.005$) by Post-Hoc Tukey.
*There were significant differences between TDS readings between SS1, SS2, and SS5.

Temporal Variation of TDS in Sungai Kuala Perlis

The temporal variation of TDS in Sungai Kuala Perlis is observed based on the results from three separate sample times conducted in the morning, afternoon, and evening. The mean TDS for the morning sampling (AM), the afternoon sampling (AF), and the evening sampling (PM), respectively, was 1549.20 1997.10 mg/L, 5280.80 4067.81 mg/L, and 4382.60 3774.40 mg/L. The sampling time and the mean value of TDS in Sungai Kuala Perlis were found to have a moderately significant association, $R^2 = 0.5291$, according to the graph presented for mean TDS for temporal distribution. The mean TDS across the temporal distribution was lowest for morning sampling compared to afternoon and evening sampling, indicating that the temporal variation of TDS could exist in Sungai Kuala Perlis. Once again, one-way ANOVA was conducted to prove the significant difference in TDS over sampling time. Figure 8 shows the mean TDS temporal variation in Sungai Kuala Perlis.

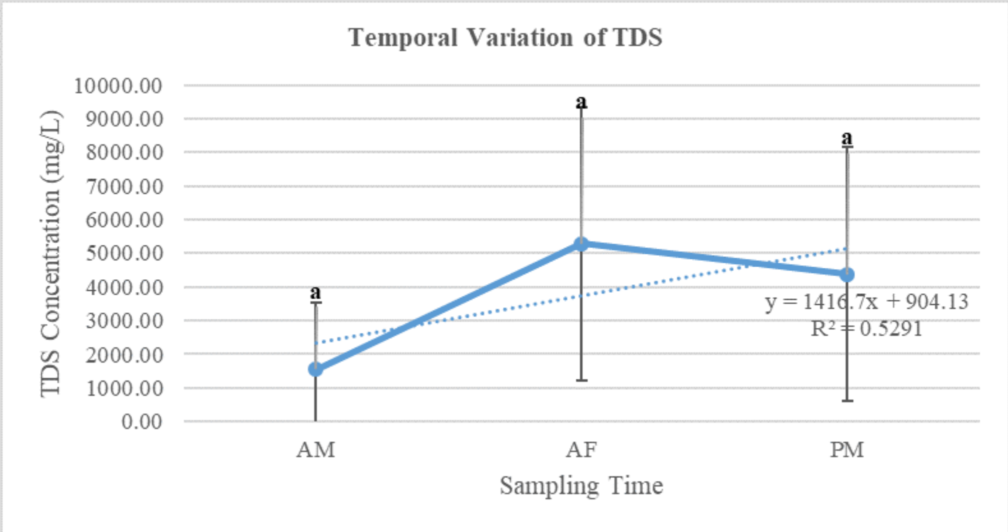

Figure 8. Mean of TDS Temporal Distribution

The influence of sampling time on surface water TDS value in the morning, afternoon, and evening was investigated using a one-way between-subject ANOVA. There was not a significant effect of the sampling time on surface water TDS value at the $p< .05$ level for the three conditions [$F (2,12) = 1.636$, $p = 0.235$], as can be seen in Table 5. According to these results, the TDS value in Sungai Kuala Perlis is unaffected by sampling time. The TDS variation in the study area, Sungai Kuala Perlis, generally did not change over time. Nevertheless, this finding was limited only within a day of sampling work to provide preliminary data of temporal variation in Sungai Kuala Perlis. Extensive data collection within seasonal or annual difference could shed more light on TDS variation in the study area. Post hoc Tukey HSD was not further performed because there was no discernible difference in the time fluctuation of surface water TDS measurement.

Table 5. One-Way ANOVA for Temporal Variation of TDS Assessment.

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		37932928.933	2	18966464.467	1.636	.235
	Linear Term	Contrast	20070388.900	1	20070388.900	1.731	.213
		Deviation	17862540.033	1	17862540.033	1.541	.238
Within Groups			139126520.800	12	11593876.733		
Total			177059449.733	14			

Impact of Total Dissolved Solids Concentration

Along with other water physicochemical properties, the rise in total dissolved solids is primarily due to the deterioration of the river health ecosystem from numerous sources of water pollution. As a result of water pollution, the conditions will damage living organisms, the environment, and riverine infrastructures. First, elevated TDS could affect the living, such as aquatic fishes and other species that reside in the same habitat. Brix et al. (2010) noted that high TDS significantly influenced embryo water absorption at concentrations as low as 964 mg/L TDS. The ecological implications of the TDS effect on embryo survival under real-world situations should be further inspected. High TDS levels also could affect humans as it could hazardously affect the health derived from water pollution. Based on the research conducted by Halder & Islam (2015) showed that the maximum TDS, turbidity, biological oxygen demand (BOD), hardness, and chemical oxygen demand (COD) concentrations observed in the Turag River, Dhaka, Bangladesh are far beyond the standard allowable limit. The report also shows that local communities deal with various health issues, including skin problems, diarrhea, dysentery, respiratory infections, anemia, and challenges after childbirth. TDS levels greater than 4500 mg/L in drinking water harmed water and feed intake, resulting in poor development performance in Murrah buffalo calves (Sharma et al., 2017). Therefore, all evidence showed that elevation in TDS level could generally and negatively impact living.

Moreover, the TDS gradient also potentially changes the environment's landscape and the biodiversity of the river stream. Regarding the ecological aspect, the TDS level could spatially differentiate or create partition between macroinvertebrate species distribution in a stream based on the osmoregulation abilities and tolerance to salinity and electrical conductivity (Olson & Hawkins, 2017). Anthropogenic land use and activity-related salinization of freshwater streams is a growing global environmental concern. Individual ion increases (such as salt or chloride), as well as combination measures such as total dissolved solids (TDS), threatened drinking water supplies, agricultural and economic interests, and the ecological health of freshwater streams (Brent et al., 2022). Elevated TDS should be considered as one of the critical factors determining river health and the degree of water pollution in a river stream (Hao et al., 2009). Water sources with higher total dissolved solids may be less appealing to consumers due to the salts present and the laxative effect they have on the transitory consumer due to the mineralization of the freshwater sources. Whelton et al. (2007) reported that at water sources with TDS at 1,000 mg/L, around 2% of the adult population might reject drinking the water, and at TDS 2,800 mg/L, 50% of the same people may refuse to drink the water. A change in total dissolved solids influences hardness, deposits, colored water, and discoloration and provides a salty flavor, lowering the water quality of freshwater sources. High dissolved solids impair freshwater's aesthetic components, affecting drinking sources (Dietrich & Burlingame, 2015). In short, TDS level in water bodies can alter the biodiversity distribution, environmental problems and alter the palatability of freshwater sources, despite of the issues, optimistically TDS also can be an ideal indicator to monitor river health and prevent water pollution to worsen.

Lastly, total dissolved solids also cause infrastructure degradation and shorten the lifespan of facilities built beside rivers or along coastlines. Total dissolved solids could operate as surrogates for ionic strength, increasing conductivity and corrosion rates in building metals (Pandey et al., 2012). This will cause a rise in the cost implemented for maintenance fees, and the brittle structure will pose a hazard risk to locals. Elevating TDS due to the greater ion concentration enhances the water's capacity to complete the electrochemical circuit and a corrosive current (Muylwyk et al., 2014). Different dissolved particles in the water will alter the production of protective coatings and trigger varied reactions on various metal complexes. For example, suppose TDS is composed of sulphate and chloride as anion contributors. In that case, it will cause corrosion on iron-based materials, whereas if TDS is predominantly composed of bicarbonate and hardness iron, it will be highly corrosive on copper but noncorrosive on iron and non-cementitious materials, as highlighted by (Muylwyk et al., 2014). Therefore, it can be concluded that understanding the properties of TDS and its component could sustain the riverine infrastructures, preserve the local region’s socioeconomics, and prepare the best marine spatial planning along the estuary or coastal area where the TDS level is significantly different and higher compared to other places. In Sungai Kuala Perlis specifically, based on the finding, TDS distribution that could be possibly impact the living, environment, and riverine infrastructures could be derived by agriculture, housing area, restaurant, solar power plant, roadside, and floating village as listed above.

Conclusion

The findings successfully acquired preliminary data on the current spatiotemporal variance in TDS assessment on the surface water of Sungai Kuala Perlis. The TDS ranges were 195.00 mg/L to 4900.00 mg/L, 325.00 mg/L to 9400.00 mg/L, and 296.00 mg/L to 8500.00 mg/L, respectively, for the morning (AM), afternoon (AF), and evening (PM) sampling times throughout five sampling stations. The research found a significant difference in the mean TDS readings concerning spatial variations ($p > .05$). However, there is no significant difference concerning temporal variations of TDS ($p < .05$) on the surface waters of Sungai Kuala Perlis. The spatiotemporal findings point to spatial heterogeneity in

TDS measurement across sampling station 1, sampling station 2, and sampling station 5 and but not at any different time in Kuala Perlis. The researcher, the government, and non-governmental organizations can use the preliminary TDS fluctuation data to prepare for the Kuala Perlis region's future social and economic growth by monitoring river health or measuring pollution. The information could also help to improve ecologically friendly river management and protect the Sungai Kuala Perlis ecosystem.

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Author Contribution

Aimie Rifhan Hashim conducted the research and wrote and revised the article. Sharir Aizat Kamaruddin, Khairul Naim Abd. Aziz and Jamil Tajam designed and supervised the research progress; Tun Mohd Firdaus Azis supervised statistical analysis; Faeiza Buyong, Che Zulkifli Che Ismail and Anisah Lee Abdullah anchored the review, revisions and approved the article submission. Anastacia Anscelly supervised the spatiotemporal study on localized geographic conditions.

Conflict of Interest

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

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