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ASSESSMENT OF THE CURRENT SPATIOTEMPORAL VARIATIONS OF TOTAL SUSPENDED SOLID ON THE SURFACE WATERS OF KUALA PERLIS, PERLIS

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ABSTRACT. *Rivers are vital water sources for human existence and environmental health. Due to freshwater scarcity, monitoring river water quality is crucial, especially concerning total suspended solids (TSS), which pose potential risks to health and the environment. Despite this importance, there is a lack of assessment of spatiotemporal TSS variation in Malaysia, particularly in Sungai Kuala Perlis. This study aims to evaluate spatial-temporal TSS variations in the surface water of Kuala Perlis, Perlis. Sampling points were GPS-recorded in December 2021. Five sites were established for morning, afternoon, and evening sampling. Water samples were collected and subjected to gravimetric analysis using the American Public Health Assessment (APHA) standard. ANOVA ($p=0.05$) in SPSS version 26 found TSS ranges of 110.67 mg/L -177.67 mg/L, 27.67 mg/L – 132 mg/L, and 78 mg/L – 304.67 mg/L for morning, afternoon, and evening, respectively. Surprisingly, no significant mean TSS differences were found for temporal ($p>0.05$) or spatial ($p>0.05$) variations. Factors influencing TSS variation such as water flow, salinity, and anthropogenic activities, were discussed. These findings inform researchers, governments, and NGOs for future planning in Kuala Perlis, promoting river health and eco-friendly management.*

KEYWORDS. Kuala Perlis, total suspended solids, water pollution, spatiotemporal study

INTRODUCTION

In recent decades, river water quality monitoring has been one of the major interesting research subjects as freshwater sources have become scarce and limited. Rivers are important sources of water for human existence and environmental health. Therefore, river water quality is a critical characteristic that must be conserved and closely monitored (Kamaruddin et al., 2018, 2021; Othman et al., 2012). Water quality, including hydrology, is a significant component of river health evaluations because it affects the spatial and temporal dynamics of various biological patterns and processes in major rivers (Kamaruddin et al., 2022; Mohd Rizal et al., 2022; Sheldon & Fellows, 2010). Studies have found that surface waters are the most polluted due to their easy availability for wastewater dumping (Kamaruddin et al., 2020; Samsudin et al., 2011). Malaysia's latest river water quality was examined in 2020 using 8,098 samples from 1,353 manual monitoring stations covering 672 rivers. Out of the 672 rivers monitored, 443 (66%) had good water quality, 195 (29%) were slightly polluted, and 34 (5%) were polluted (Department of Environment, 2020). The quality of water varies temporally and spatially because alterations in land cover surrounding rivers change over time and in different locations, influenced by both anthropogenic and natural factors (Hashim et al., 2023). This variability makes determining water conditions and pollution sources difficult and crucial for effective pollution control (Kamaruddin et al., 2021). Water quality monitoring should be conducted to properly understand rivers' current river health assessment, especially regarding the total solid content in the river ecosystem.

The total solid content in water bodies has adverse and detrimental effects on health and the ecosystem. Solids can degrade the quality of water or wastewater in various ways, and controlling biological and physical wastewater treatment processes requires solids analyses (Al-Badaii et al., 2013; Kamaruddin et al., 2020). Total solids include "total suspended solids," which a filter retains, and "total dissolved solids," which go through the filter (American Public Health Association, 1999). TSS is solid in water, including silt, decomposing materials, industrial waste, and sewage (Mohamed et al., 2015). TSS is a water quality indicator used to study sediment transport, aquatic ecosystem health, and engineering issues. Natural and anthropogenic processes such as runoff, coastal erosion, dredging activities, and waves account for most TSS in water bodies (Sa'ad et al., 2021). In short, a total suspended solid analysis should be carried out to understand the current river health in Malaysia.

Moreover, the total suspended solid is already an essential parameter in water quality monitoring in Malaysia. In the middle of the estuary and farther downstream, the TSS level increased due to wastewater dumping, an influx of runoff from the upper reaches, and fish feed for caged fish farming in Merbok Estuary (Fatema et al., 2014). The dry season has greater TSS levels than the wet season in Merbok Estuary (Fatema et al., 2014). However, this is contrary to a study conducted by Al-Badaii et al. (2013) in the Semenyih River, Selangor, as the rainy season had the highest TSS values because of the rainy season days, which caused substantial erosion on both sides of the riverbanks. According to the Malaysia Marine Water Quality and Criteria Standard, the allowable TSS amount for Class E (Interim) should be 30 mg/L (Department of Environment Malaysia, 2017). Therefore, the study of TSS in monitoring the river water quality assessment should be continually studied to acknowledge their adverse roles or impact on water bodies, especially in Sungai Kuala Perlis.

Previous studies showed that Sungai Kuala Perlis is designated as a Class III river, and it is currently undergoing severe erosion along its river banks and has become extremely shallow. Kuala Perlis has a landfill, directly impacting the river's water quality. Squatters near the river reserve area are also causing pollution. Shrimp livestock ponds, Kangar Wet Market, Sungai Perlis Esplanade, food vendors, and the Kuala Perlis Fisherman Jetty are further polluting sources (Samsudin et al., 2011). Previously, in 2006, Sungai Perlis had WQI scores of 68, which shows the status of slightly polluted and categorized as Class III (Department Of Environment, 2006). In 2019, Sungai Perlis' WQI scores ranged from 76 to 91, with only one river, Sungai Serai, being mildly contaminated (WQI score of 76, Class III); however, by 2020, the Sungai Perlis Basin's WQI had recovered to a range of 82 - 94 WQI scores, with all rivers classified as clean (Class I and Class II) (Department of Environment, 2020). Based on the current environmental report, Sungai Kuala Perlis's water quality has gradually been cleaned. The most recent study in Sungai Kuala Perlis revealed no significant variation in mean pH levels based on temporal variability. Despite the fact that the study discovered a considerable variance in pH readings due to spatial variations, the current spatiotemporal variation of TSS in Sungai Kuala Perlis is still not fully understood (Hashim et al., 2022). Prolonged and continued observation should be conducted to understand the current spatiotemporal variation of total solid content in Sungai Kuala Perlis.

Spatiotemporal variation of total suspended solids in Sungai Kuala Perlis should be properly conducted to assess the current condition and recent river health risk assessment. Temporally, water quality during high tide is Class II for upstream and downstream of the river. However, it is Class III during low tide. These results revealed that the river was less contaminated during high tide than during low tide. The volume and flow of water can impact the river's water quality. However, there were no variations in WQI during high and low tides in the river's mainstream, classified as Class III (Che Ali et al., 2020). The TSS values at Sungai Perlis were higher during low than high tide (Che Ali et al., 2020). Spatially, according to Amneera et al. (2013), from Station 1 to Station 3, the TSS value was 50.25 mg/L, 30 mg/L, and 68.75 mg/L, respectively, from sample water taken in Sungai Kuala Perlis. Station 2 is classified as Class II, while Station 1 is classified as Class III, based on the NWQS parameter restrictions for Malaysia. Station 3 is Class III, with 50 to 150 mg/L concentrations. Previously, TSS profiles in Sungai Perlis exhibited fluctuations during high and low tides. In high tide, TSS levels ranged from 16.67 mg/L upstream, 30.25 mg/L in the middle stream, to 26.6 mg/L downstream. During low tide, TSS concentrations notably increased, with values of 42.67 mg/L upstream, 60.65 mg/L in the middle stream, and 57.34 mg/L downstream (Che Ali et al., 2020) . However, comprehensive and up-to-date data on the spatiotemporal variations of total suspended solids in Sungai Kuala Perlis remains limited. This study was initiated to provide preliminary data on the current assessment of the spatiotemporal variation of total suspended solids in Sungai Kuala Perlis and to understand the influence of the current anthropogenic landscape along with the river bodies that might be responsible for the pollution.

MATERIALS AND METHODS

This section briefly explained the sampling method, selection of sampling sites, and gravimetric analysis of total suspended solids. The observation during sampling activities was recorded to provide possible anthropogenic activities affecting the water quality and total suspended solid content.

Sampling method

Sampling was conducted in early December 2021, and five places were established, beginning with the first (SP1), Jetty Tok Kuning, and continuing until the river's mouth, the fifth location (SP5). Each sampling site was meticulously documented and recorded using the Global Positioning System (GPS). The sampling was done in the morning, afternoon, and evening. Water samples were obtained around one meter beneath the surface. At each sampling site, observations were made focusing on the natural landscape and potential anthropological components that could alter water quality and total solid content distribution. The water samples were collected in 1.5-litre plastic bottles, carefully labelled according to sampling sites, and transported to the laboratory for further investigation. Figure 1 illustrates the flow chart for TSS assessment in Sungai Kuala Perlis.

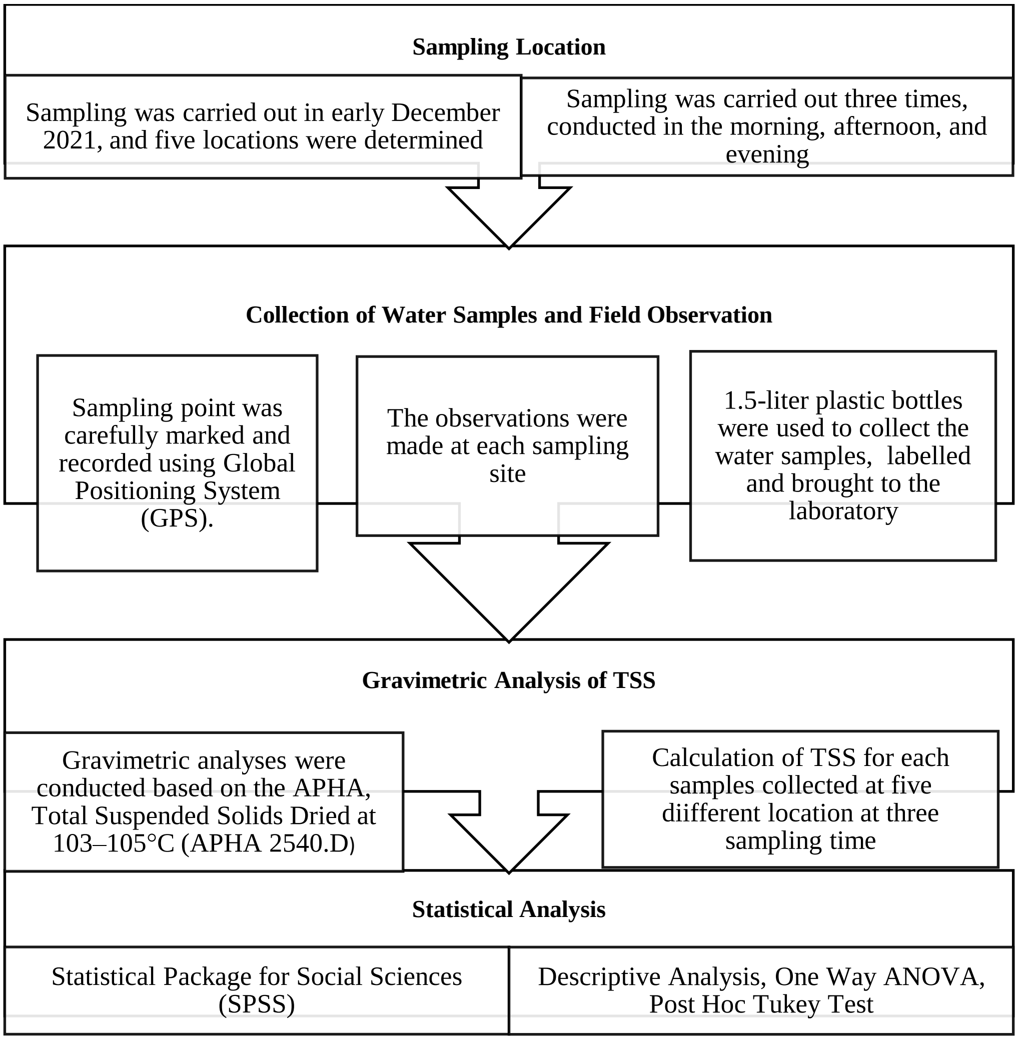

Figure 1. Flow chart for TSS assessment in Sungai Kuala Perlis

Sampling point location

The sampling sites were visited at three separate times: morning (AM), afternoon (AF), and evening (PM). During surface water sampling, each sampling point will be labelled (SP1-SP5), and the latitude and longitude will be recorded using a GPS. During the sample activities, probable anthropogenic activities were seen, and Table 1 indicates the sampling location and possible anthropogenic activities observed.

Table 1. Sampling location and possible anthropogenic activities

Sampling	Location	Coordinate	Possible Anthropogenic Activities
AM	SP1	6˚25'04.853"N 100˚09'01.853"E	Jetty Tok Kuning, Agriculture
	SP2	6˚25'19.128"N 100˚08'32.333"E	Agriculture, Aquaculture/ Fishing Pond
	SP3	6˚25'03.461"N 100˚08'22.434"E	Solar Power Plant
	SP4	6˚24'37.799"N 100˚08'23.903"E	Solar Power Plant, Roadside, Residential Area
	SP5	6˚24'28.511"N 100˚08'23.364"E	Restaurant, Floating Village
AF	SP1	6˚25'04.992"N 100˚09'00.774"E	Jetty Tok Kuning, Agriculture
	SP2	6˚25'17.364"N 100˚08'46.409"E	Agriculture, Aquaculture, Fishing Pond
	SP3	6˚25'20.808"N 100˚08'31.746"E	Fish Pond, Solar Power Plant, Roadside
	SP4	6˚24'57.449"N 100˚08'18.917"E	Roadside, Restaurant
	SP5	6˚24'27.263"N 100˚08'20.742"E	Floating Village
PM	SP1	6˚25'04.787"N 100˚09'01.290"E	Jetty Tok Kuning, Agriculture
	SP2	6˚25'22.188"N 100˚08'44.322"E	Agriculture, Aquaculture, Fishing Pond
	SP3	6˚25'00.653"N 100˚08'19.679"E	Aquaculture, Solar Power Plant
	SP4	6˚24'34.355"N 100˚08'29.033"E	Solar Power Plant, Roadside, Residential Area
	SP5	6˚24'27.479"N 100˚08'23.364"E	Restaurant, Floating Village

Furthermore, sampling locations in Sungai Kuala Perlis were plotted for surface water collection based on latitude and longitude for each sampling time. The map allows for precise sampling point positioning, and possible anthropogenic activities can be thoroughly investigated. Figure 2 (Google Earth, 2022c) showed the sampling location for morning (AM) sampling; Figure 3 (Google Earth, 2022a) showed the sampling location for the afternoon (AF) sampling, and Figure 4 (Google Earth, 2022b) showed the sampling location for the evening (PM) sampling.

Figure 2. Morning sampling location (Google Earth, 2022c)

Figure 3. Afternoon sampling location (Google Earth, 2022a)

Figure 4. Evening sampling location (Google Earth, 2022b)

Gravimetric analysis of total suspended solids

Gravimetric analyses were conducted based on the APHA, Total Suspended Solids Dried at 103–105°C (APHA 2540.D) standard procedures in assessing solid analysis (American Public Health Association, 1999). Sample water collected for each sampling point (SP) will be tested for three batches of the sampling period, morning sampling (AM), afternoon sampling (AF), and evening sampling (PM).

Determination of total suspended solids

The filtering apparatus was assembled; 27 mm diameter, 0.45 µm-porous size was used in this analysis. The filter was seated first with a little reagent–grade or distilled water. 300mL of the sample was used for each sampling point. If possible, shear bigger particles with a magnetic stirrer to get a more uniform (ideally homogeneous) particle size. While stirred, 300 mL of sample were pipetted into the receiving flask, and suction was commenced. The filter was washed with three successive 10-mL volumes of reagent-grade water, complete drainage between washings was allowed, and suction was continued for about 3 min after filtration was complete. Samples with high dissolved solids may require additional washings. The filter was carefully removed from the filtration apparatus and transferred into an aluminium weighing dish as support. The filter was dried for at least 1 hour at 103 to 105°C in an oven, cooled in a desiccator to balance temperature, and weighed. The cycle of drying, cooling, desiccating, and weighing until a constant weight is obtained or until the weight change is less than 4% of the previous weight or 0.5 mg, whichever is less. 10% of all samples were analyzed in duplicate. The weight of the filter, and the residue were recorded, and the TSS value was calculated. Figure 5 shows the filter retaining the TSS before drying (a) and dried filter paper retaining TSS (b).

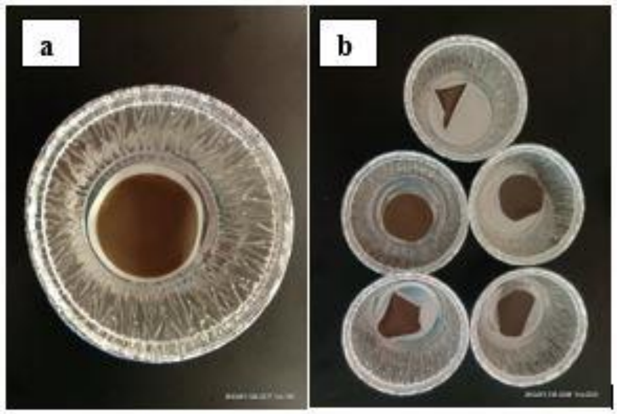

Figure 5. Filter retaining TSS before drying (a) and dried filter paper retaining TSS (b)

Calculation of TSS

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

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

Where:
A = weight of filter + dried residue, mg
B = weight of filter, mg

RESULTS AND DISCUSSION

All the results obtained from the spatiotemporal finding for Kuala Perlis's TSS variation were discussed distinctly for temporal and spatial variation of TSS, respectively, at Sungai Kuala Perlis. The data were tabulated and illustrated in tables and figures, respectively. The data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 26. The current TSS spatiotemporal variation and possible factors affecting the spatiotemporal variation of TSS were further discussed.

Spatiotemporal variation of TSS in Sungai Kuala Perlis

The results showed three distinct ranges for TSS measurement along Sungai Kuala Perlis. For TSS, the ranges recorded for the morning, afternoon, and evening were 110.67 mg/L – 177.67 mg/L, 34.00 mg/L – 132.00 mg/L, and 78.00 mg/L – 304.67 mg/L, respectively, for the morning (AM), afternoon (AF), and evening (PM) sample times. The spatiotemporal variation of TSS will be discussed further below. Table 2 contains the distribution of the TSS for the five sampling points and the three sampling times.

Table 2. Data collection of TSS distribution at Sungai Kuala Perlis

Sampling	Location	TSS (mg/L)
AM	SP1	162.33
	SP2	145.33
	SP3	166.33
	SP4	177.67
	SP5	110.67
AF	SP1	132.00
	SP2	128.33
	SP3	50.00
	SP4	27.67
	SP5	34.00
PM	SP1	125.00
	SP2	304.67
	SP3	78.00
	SP4	111.33
	SP5	86.67

Spatiotemporal Variation of TSS

For the TSS spatiotemporal variation, it is apparent that the highest mean TSS was recorded during evening sampling at SP2 compared to the others. On the contrary, the lowest mean of TSS was recorded at the SP4 during the afternoon sampling. The ranges of the TSS distribution in the morning, afternoon, and evening were 110.67 mg/L – 177.67 mg/L, 27.67 mg/L – 132.00 mg/L, and 78.00 mg/L – 304.67 mg/L throughout five locations. Thus, it can be seen that TSS is particularly higher in the inshore part of the river compared to the region near the sea. The sampling point 2 (SP2) also showed the highest peak compared to the other location at a mean TSS of 192.78 ± 97.27 mg/L, while the lowest mean TSS was observed at SP5 with a mean TSS value of 77.11 ± 39.22 mg/L. Overall, from the plotted graph, it can also be seen that the TSS distribution is consistently higher during the morning sampling

(AM) exception at the SP2. The research predicted that the TSS value at the SP2 can be dramatically affected by the anthropogenic activities near the sample water collected; from the map and observation, SP2 can be seen near the agriculture site, aquaculture site, and fishing pond. The TSS might increase due to the scheduled water exchange of the aquaculture or fishing pond nearby. TSS spatiotemporal variation in Sungai Kuala Perlis is illustrated in Figure 6. Spatial and temporal variation of TSS along Sungai Kuala Perlis were recorded and analyzed in detail to understand the pattern of changes and to determine the current spatiotemporal variation of TSS on the surface waters of Sungai Kuala Perlis.

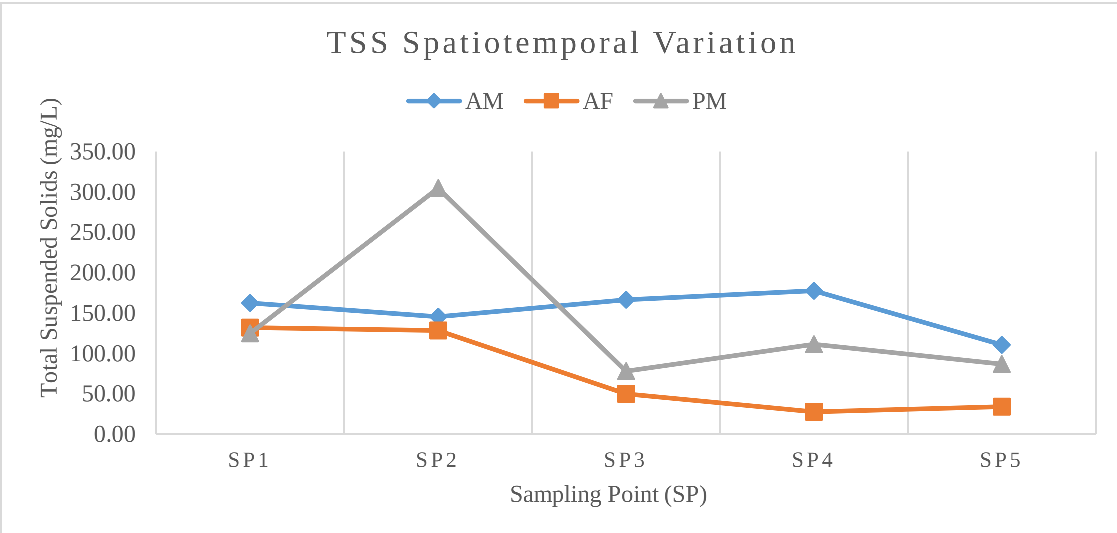

Figure 6. TSS spatiotemporal variation in Sungai Kuala Perlis

Spatial variation of TSS in Sungai Kuala Perlis

Spatially, the distribution of the total suspended solids was recorded. The finding revealed that the mean distribution of TSS at five different locations was 139.78 ± 19.84 mg/L, 192.78 ± 97.27 mg/L, 98.11 ± 60.72 mg/L, 105.56 ± 75.17 mg/L, 77.11 ± 39.22 mg/L, from SP1 till SP5. The highest mean TSS recorded for each sampling was at SP2. In contrast, the lowest mean of TSS was recorded at the fifth sampling point (SP5). A strong correlation, R2 = 0.5524, was found between the sampling point and the mean value of TSS at different sampling locations in Sungai Kuala Perlis. The mean TSS spatial distribution in Sungai Kuala Perlis is illustrated in Figure 7 below.

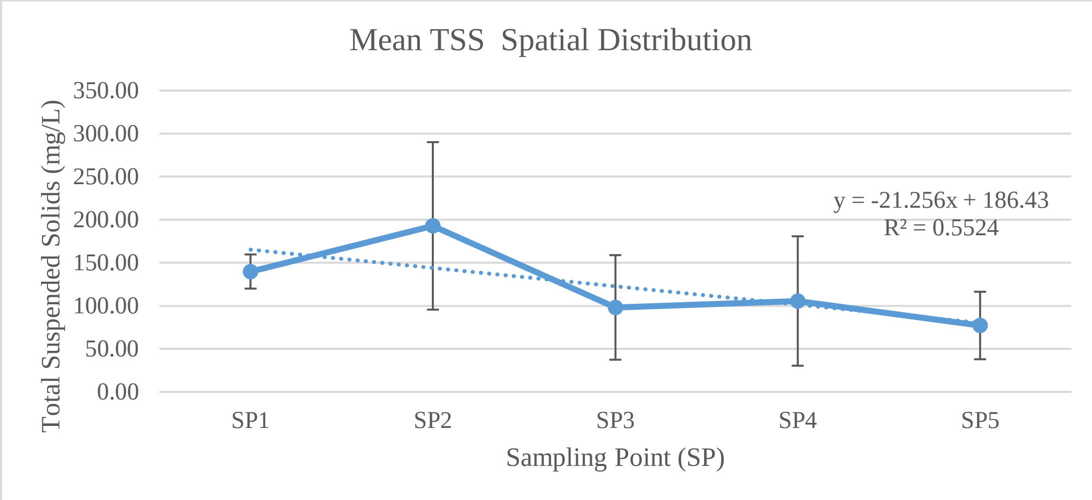

Figure 7. Mean of TSS spatial distribution

A one-way between-subject ANOVA was used to determine how the sampling point (SP1–SP5) affected the TSS value of the surface water in Sungai Kuala Perlis. At the $p < .05$ level for the five chosen sample points, there was no evidence of a substantial impact of the sampling location on the TSS value of surface water [$F(4,10) = 1.480$, $p = 0.280$], as can be seen in Table 3. These findings imply that the sampling site does not alter the TSS value of the water surface. In general, TSS assessment did not vary spatially in the study area of Sungai Kuala Perlis. As there was no significant difference in the spatial variation of surface water TSS measurement, post hoc Tukey HSD was not further performed.

Table 3. One-way ANOVA for spatial variation of TSS assessment

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		24538.296	4	6134.574	1.480	.280
	Linear Term	Contrast	13553.959	1	13553.959	3.269	.101
		Deviation	10984.337	3	3661.446	.883	.482
Within Groups			41460.148	10	4146.015		
Total			65998.444	14			

Temporal Variation of TSS in Sungai Kuala Perlis

For the temporal variation of TSS in Sungai Kuala Perlis, the temporal variation is observed based on the results obtained at three different sampling times conducted in the morning, afternoon, and evening. The mean TSS for each sampling time was 152.47 ±26.09 mg/L for the morning sampling (AM), 74.40 ±51.57 mg/L for the afternoon sampling (AF), and 141.13 ±93.33 mg/L for evening sampling (PM), respectively. From the plotted graph for mean TSS for temporal distribution, a weak correlation, R2 = 0.018, was found between the sampling time and the mean value of TSS in Sungai Kuala Perlis. The lowest mean TSS for temporal distribution was during afternoon sampling compared to morning and evening sampling. Figure 7 shows the mean TSS temporal distribution.

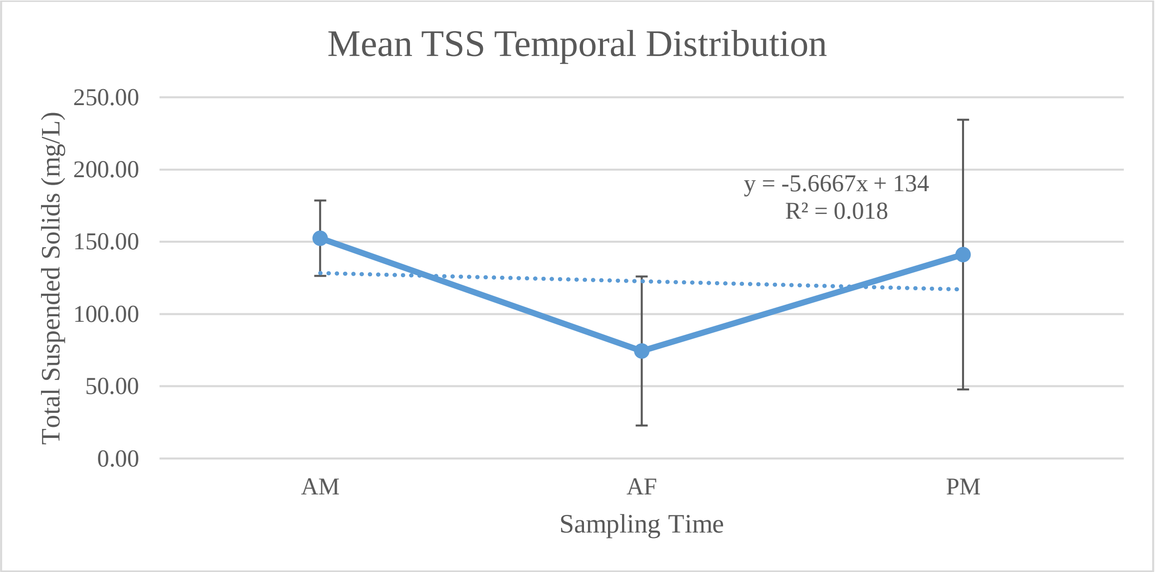

Figure 8. Mean of TSS temporal distribution

A one-way between-subject ANOVA was conducted to study the effect of the sampling time on surface water TSS value in the morning, afternoon, and evening. There was not a significant effect of the sampling time on surface water TSS value at the $p < .05$ level for the three conditions [$F(2,12) = 2.215$, $p = 0.152$], as can be seen in Table 4. These findings imply that sampling time in Kuala Perlis has no impact on TSS value. The TSS evaluation in the research region, Kuala Perlis River, generally did not vary over time. Since there was no significant difference in the time fluctuation of surface water TSS assessment, post hoc Tukey HSD was also not further performed.

Table 4. One-way ANOVA for temporal variation of TSS assessment.

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		17793.644	2	8896.822	2.215	.152
	Linear Term	Contrast	321.111	1	321.111	.080	.782
		Deviation	17472.533	1	17472.533	4.350	.059
Within Groups			48204.800	12	4017.067		
Total			65998.444	14			

Possible Factors Affecting Spatiotemporal Variation of TSS Distribution in Kuala Perlis River

In recent years, several studies have focused on the possible factors affecting the spatiotemporal variation of total suspended solids distribution in water bodies. Factors affecting the spatiotemporal distribution of TSS in river bodies are water flow rate, salinity, tidal movement and anthropogenic activities (Che Ali et al., 2020; Che Ngah et al., 2012; Dhungana & Wang, 2020; Håkanson, 2006; Rossi et al., 2006).

Researchers have studied the flow rate's effect on water bodies' total suspended solid distribution. Studies found that water flows positively influenced the TSS distribution in water bodies. A study by Dhungana & Wang (2020) confirmed that the flow rate increases the TSS concentration and eventually permits dam failure. TSS content in the water bodies, especially in lower drainage basins, is highly responsive to variations in flow rate (López et al., 2021). During frontal occurrences with extremely high peak flows in the examined estuaries, the average TSS values were higher than the other times. In short, spatially, the region with a high flow rate has higher TSS content. The collective finding indicates that water flow rate affects the spatiotemporal variation of TSS in river bodies.

Another factor that influences the distribution pattern of TSS concentration in river bodies is salinity. The dynamics of the inflow's salinity regime changes significantly impact the TSS concentration in estuaries and can assist in preserving nutrients (Paudel et al., 2019). It has been suggested that salinity could be a determining factor in the aggregation of the total suspended solids due to the presence of the salt ion (Håkanson, 2006). Therefore, the segmentation difference in freshwater and estuary in terms of salinity influences the spatiotemporal distribution of TSS in river bodies. The previous study found that salinity ranges along the Sungai Kuala Perlis ranged from 0.41 to 5.00 ppt, 0.79 to 24.74 ppt, and 0.33 to 14.00 ppt for the morning, afternoon, and evening periods (Hashim, Kamaruddin, Abd. Aziz, Tajam, Buyong, Abdullah, et al., 2023). The mean TSS for each sampling time was 152.47 ±26.09 mg/L for the morning sampling, 74.40 ±51.57 mg/L for the afternoon sampling, and 141.13 ±93.33 mg/L for the evening sampling respectively. Consequently, research can highlight the connection between increased salinity and decreased TSS, especially during the afternoon sampling.

Moreover, the variation of TSS also being influenced by the daily tidal movement in Sungai Kuala Perlis. On Saturday, December 4th, 2021, in Kuala Perlis, the sunrise occurred precisely at 7:16:00 a.m., and the sunset took place at 7:02:50 p.m. The analysis of high and low tide data reveals specific timing, with the initial low tide recorded at 6:11 a.m., followed by another low tide at 6:02 p.m. The solitary high tide of the day was observed at 12:16 p.m. (tides4fishing.com, 2023). Consequently, the finding indicates that the TSS concentrations are significantly higher during low tide compared to high tide. This discovery aligns with the findings reported by Che Ali et al. (2020), which noted the elevation of TSS values during low tide conditions along Sungai Perlis compared to high tide conditions. It is postulated that the flow dynamics of the river during tidal events play a substantial role in regulating the concentration of both organic and inorganic materials within the river, driven by variations in river volume during high and low tides. During high tide episodes, TSS readings are reduced as dilution occurs due to the increased water volume.

In addition, the factor that influences the TSS spatiotemporal variation is anthropogenic activities. Typically, anthropogenic sources in rivers come from land-based sources, including mining, factories, and riverside development, which may influence the water quality, especially TSS (Azrina et al., 2006). In particular, sewage effluent and nutrient runoff from nearby residential areas can impact the TSS pollutants in river water (Bello & Haniffah, 2021; Tengku Ibrahim et al., 2021). Thus, anthropogenic activities are a major factor influencing the spatiotemporal variation of TSS content in river bodies.

To summarize, concerning Sungai Kuala Perlis, the water flow rate, salinity, and anthropogenic activities are possible factors affecting the TSS value in river bodies. The construction of a new residential area and other human activities close to Sungai Perlis have disturbed the soil surface, resulting in river pollution, erosion, increased runoff, and large-scale sediment movements (Che Ali et al., 2020). Sungai Kuala Perlis has become an alternative pathway for fishing vessels moving from the jetty to the sea, especially along the studied area. Thus, the water flow rate possibly increases from time to time, thus causing TSS suspension to rise on the surface. Different salinities of Sungai Kuala Perlis, from the jetty (SP1) moving forward approaching the sea, could also influence the TSS concentration. From the observation made during the sampling, there are rapid and dense human activities along Sungai Kuala Perlis, such as agriculture (paddy fields), aquaculture (aquaculture and fishing pond), floating residential areas, restaurants, and fresh markets. Floating trash and debris also can be seen free-floating along the stream flow. Figure 9(a) showed fishing vessels along Sungai Kuala Perlis; Figure 9(b) (Residential Area/Fishers Village) and Figure 9(c) depicted evidence of free-floating trash and debris.

Figure 9. (a) fishing vessels along Sungai Kuala Perlis; (b) Residential area/fishers village and (c) evidence of free-floating trash and debris.

CONCLUSIONS

The findings effectively obtained preliminary data on the current spatiotemporal variance in TSS assessment on the Sungai Kuala Perlis surface water. The TSS results range was 110.67 mg/L -177.67 mg/L, 27.67 mg/L – 132 mg/L, and 78 mg/L – 304.67 mg/L, respectively, for the morning, afternoon, and evening sampling. However, the research found no significant difference in the mean TSS readings concerning temporal spatial variations. The study found no spatiotemporal variability in TSS measurements at any of the surface water locations and at any different time in Kuala Perlis. The preliminary information on TSS fluctuation can be used by the researcher, the government, and non-governmental groups to plan for future social and economic growth in the Kuala Perlis region by monitoring river health or assessing pollution. The data might also enhance environmentally friendly river management and safeguard the Sungai Kuala Perlis ecosystem.

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