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Short communication

Assessment of Seasonal and Spatial Surface Marine Water Quality Variation in Semerak River Estuary, Malaysia

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Abstract

Mangrove estuary is a part of the mangrove ecosystem which plays an important role for the whole ecosystem. Purposely, this study is to assess the spatial and seasonal variation of surface marine water quality in Semerak River estuary. Dissolved oxygen (DO), unionized ammonia (NH_3N), total suspended solid (TSS), nitrate (NO_3), oil and grease (O&G), phosphate (PO_4), faecal coliform (FC), pH, salinity and conductivity are the measured parameters using in-situ and ex-situ technique. Surface marine water samples collected in two monsoon -Southwest Monsoon (July 2016 to September 2016) and Northeast Monsoon (November 2016 to January 2017). The analytical and statistical results indicate that the surface water of the Semerak River estuary that the possible pollution sources coming from major agriculture, fertilizers, fishing boat and sand mining, natural environment from weathering of geologic sources, surface runoff and oil-spill from fishing boat. Marine water samples of future monitoring studies in mangrove estuary will benefit by enabling understanding of pollution loading and coastal water quality. It is essential to plan a workable water quality modelling as powerful tool to simulate marine water quality and forecast future consequences to facilitate mangrove biodiversity conservation. The chemical composition of surface marine water in both season is strongly influenced by anthropogenic inputs.

Keywords: *marine water quality; marine water quality index; mangrove, estuary; anthropogenic discharges; pollution*.

1. Introduction

Mangrove estuary is a part of the mangrove ecosystem which plays an important role for the whole ecosystem due to numerous natural specialties inside a little territory, as it is related with high organic decent variety. Anthropogenic disturbance imperil the estuaries by contaminating the water. Anthropogenic activities can add to the risky drinking water and shoreline, decrease in fisheries, shutting of shellfish bed, forfeiture of habitat, as well as destructive algal blossoms which affected human health and natural resource conundrums. Nowadays, mangroves ecosystems in Malaysia are exposed to urbanisation areas and disturbed by urban and industrial run-off which comprises traces of heavy metals in dissolved form [1]. These extraneous organic and inorganic chemicals released by these urban communities and industries indicate injurious effects which cause detriment to the environment. Above a certain pollutant threshold, the pollutant-responsive biomarker would eventually lead to the manifestation of multiple effect situation at higher hierarchal levels of biological organization.

Since no provincial or national conclusions can be drawn about the inclusive health of Malaysia's estuaries, these issues tend to cause decreases in water quality, living resources, and general the health of mangrove ecosystem. Mangrove forest shows decreases in biodiversity which resulted from mangrove forest ecosystems disturbance and the estuary as well. Commonly, a few parameters such as temperature, pH, salinity, oxidation reduction potential and electrical conductivity values more or less followed tidal cycle with high values at high tides [2]. Besides, Gavio et al. [3] stated, blending of seawater and freshwater at low and high tides on hourly time scale ascertain vigorous changes of nutrients as well as physicochemical properties. Thus, amount of changes will depend on tidal state and amplitude of coastal water.

Coastal zones presently give living space to approximately 55 % of the total population. Human draws vigorously on mangrove ecosystems for nourishment including aquaculture and shrimp cultivating, urban and industrial development, transportation, recreational and tourism uses and waste disposal [4]. The potential effect of the debasement of these ecosystem on groups, human health, nourishment security, biodiversity preservation, the health of organisms and food security will be duplicated with the growth of populations. Due to the increase of human population growth, the exploration of mangrove forest through human activities such as logging activities, deforestation, agricultural land, aquaculture activity and waste from industry gives negative impact to the environment as well as, connectedly, the water quality of mangrove forest [5]. Alas, there were more destructive impacts on the mangroves.

It was reported that the loss of mangroves will also reduce marine water quality, eradicate fish nursery habitats, decrease biodiversity and affect the adjacent coastal habitats [6]. Besides, mangroves loss might affect the tourism income for the country and cause the demolition of the mangrove ecosystem especially flora and fauna [7]. Although it was stated that water can load pollution naturally without decreasing in quality [8]. Overflow of pollutant as it reaches its maximum capacity is dangerous to living organism. Anthropogenic influences as well as natural processes degrade

surface waters and impair their use for drinking, industry, agriculture, recreation and other purposes. Changes in the species composition and the decline in the overall health of aquatic organisms have been occurring due to the deterioration of water quality.
A well-defined spatial and temporal heterogeneity in distribution of different water quality parameters was observed in the study areas. Spatial distributions and temporal variability in water chemistry in river estuary is promptly related to various factors. Rivers and estuaries are highly heterogeneous at different spatial scales [9]. The spatial heterogeneity within the river is because of local environmental conditions such as light, temperature, salinity, discharge, and water velocity that change through time and differences in local channel form. Meanwhile, degree of temporal variability of surface water chemistry diverges as a function of estuary type and influenced by the chemical parameter of interest. This variation may also be due to both hydrologic inputs which can originate from precipitation, direct overland flow, subsurface flow through shallow soils, drainage from shallow and deep aquifers, and in stream processes which include dilution, metal release, and adsorption from sediments along with precipitation [9, 10].
During Southwest Monsoon (SWM) or dry season, the recorded rainfall, runoff, and river inflow from upstream to the estuary have decreasing trends; and there is an increasing trend for salt water intrusion which mainly appears in the junction of rivers and oceans from April to September. While in Northeast Monsoon (NEM) or wet season, the intensity of salt water intrusion decreased due to the large river inflow from upstream to the estuary from October to March. Overall, the concentrations of MWQ parameters in surface waters are significantly higher during the SWM than that during the NEM, which is due to the dilution by large amount of rainfall and stream flow from upstream in the NEM [11, 12, 13]. During the NEM, the rainfall intensity and runoff all influence the dilution effects of accumulated contaminants and their transportation to the receiving water [13].
This, consecutively, is essential for evaluating the water quality of different sources and in observing the changes in the water quality of a given source as a function of time and other influencing factors [14]. In view of the significance of the mangrove to diverse aspects of the environment, this research concentrated of the surface marine water quality parameters for spatial and temporal at mangroves area as well as their distribution will be carried out.

2. Methodology

2.1. Study area

The sampling points were determined before the sampling activities to accessible and exactly signify the existing pollution sources based on 13 MWQ parameters from DOE criteria (Class E). Surface marine water samples has been collected in two monsoon which are Southwest Monsoon (July 2016 to September 2016) and Northeast Monsoon (November 2016 to January 2017). Six sampling points has been chosen in Semerak River estuary (Fig. 1). The description of the sampling points as shown in Table 1. Semerak River estuary is originated from Semerak River Basin which is semi-enclosed lagoon with a total area 1.7 km^2 with an average depth of 3.12 m located in Pasir Puteh, Kelantan. The lagoon at Semerak River estuary contain 5 304 000 m² water during high tide [15]. On the contrary for spatial distributions analyses, Semerak River estuary comprise six sampling station (SM1, SM2, SM3, SM4, SM5 and SM6). SM1 is consider as control station because of lowest salinity level between all SM sampling stations (below than 0.1). Moreover, there is no point source at SM1 from observation during water sampling activity and hardly any visible human activities in the surrounding.

Table 1: Description of sampling stations in Semerak River estuary.

Station	Latitude	Longitude	Description
SM1	5° 50' 56.727"	102° 26' 16.461"	Tok Bali Watergate
SM2	5° 52' 39.018"	102° 27' 50.2092"	Tok Bali fishing port LKIM
SM3	5° 53' 24.0072"	102° 28' 49.602"	Tok Bali fish mart
SM4	5° 51' 54.8994"	102° 29' 38.58"	Semerak fish farming
SM5	5° 51' 45.6984"	102° 30' 48.4302"	Marsh clam area (lagoon)
SM6	5° 51' 56.4444"	102° 30' 22.2876"	Marsh clam area (lagoon)

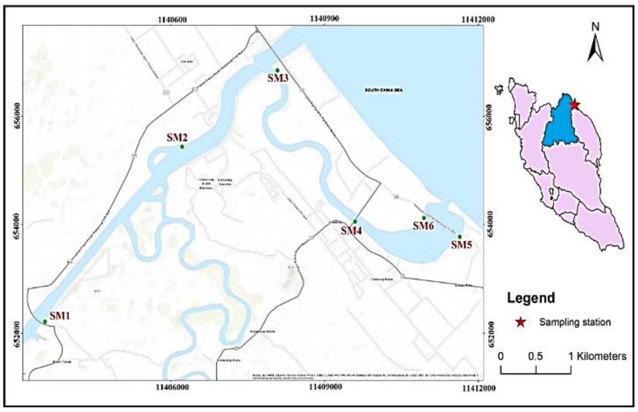


Fig. 1: Location of sampling stations in Semerak River estuary

2.2. Clean laboratory procedure for MWQ sampling and analysis

All the laboratory apparatus, glassware and 1 L high density polyethylene (HDPE) bottles were pre-cleaned with 5 % concentrated nitric acid, HNO_3 (Merck, Germany) and rinsed with deionized water to eliminate all traces of contaminants and evade potential cross-contamination.

2.3. Surface marine water sampling

The MWQ parameters selected in this study refers to the Marine Water Quality Index (MWQI) [16] as a guideline which include dissolved oxygen (DO), unionized ammonia (NH_3N), total suspended solid (TSS), nitrate (NO_3), oil and grease (O&G), phosphate (PO_4) and faecal coliform (FC). Additional MWQ also monitored for in situ such as pH, salinity and conductivity.
Triplicates and homogenized surface water samples were collected from all six sampling stations during July 2016 to January 2017. The water samples were collected during normal tide from all sampling stations. The surface water samples have been taken using water sampler (vertically) because the depth is only 30 cm. All the samples were kept in acid-washed 1 L high density polyethylene (HDPE) bottles and transported to the laboratory at < 4 °C. Surface water quality was measured onsite for the in-situ parameters at each station for temperature, pH, salinity, conductivity, DO and NH_3N at one meter below the water surface using parameter probe YSI Multi Parameter Water Quality Sonde (YSI 556, USA). Immediately after sampling, the samples were transferred into the cooler box with dry ice and transport back to the laboratory within 24 hours of sampling time.

2.4. Analytical procedure for physico-chemical parameters

The reagents and laboratory apparatus used for water analysis are shown in Table 2. The reagents used are analytical grade to protect reliable representatives from all analysis results. Additionally, laboratory glassware and apparatuses used in this study were pre-cleaned with 5 % HNO_3 (Merck, Germany), 1 ml of water sample was transferred into a 10 ml PP volumetric flask and made up to

10 ml with 1 % Suprapure grade HNO_3 solution, prepared from ultrapure water from Milli-Q® (Merck, USA). Besides, ultrapure water from Milli-Q® also used for laboratory applications.

Table 2: Summary of reagent and laboratory equipment for MWQ parameter analysis.

Parameter	Equipment	Reagent/Chemical
DO, Temp, Sal, Cond, TDS, NH_3N	YSI Multi Parameter Water Quality Sonde (YSI 556)	
Faecal Coliform	3M™ Petrifilm EC Plate; incubator	
Oil and Grease	separatory funnel; filter paper	HCL;100 % n-hexane; Na_2SO_4
NO_3	HACH meter (DR2800); HACH Reactor (DRB 200)	NitraVer5, Nitrate reagent powder pillow
PO_4	HACH meter (DR2800); HACH Reactor (DRB 200)	PhosVer3, Phosphate reagent powder pillow, Test 'N Tube
TSS	vacuum pump; membrane filter	

2.5. Data Analysis

All statistical analyses were carried out using XLSTAT (Addinsoft, France). Data was checked for inconsistencies before analysis. The initial normality test unveiled that the data was not normally distributed. Pre-treatment of data through data assemblage and transformation were carried out. According to [17], any non-detected values were replaced by half of the method detection limit. The normality of the data was also tested using Shapiro Wilk and Jarque-Bera test.

The descriptive statistics (i.e. mean, maximum, minimum, standard deviation and coefficient of variance) were computed and represented in Box and Whiskers plot. Furthermore, the statistical significance difference between all MWQ parameters were evaluated using one-way analysis of variance (ANOVA). In regard to multiple comparisons, the variables were statistically compared using Tukey-Kramer analysis at the confident level of 95 %.

3. Results and Discussion

Characterization of spatial and temporal changes in surface water quality is an important aspect for evaluating MWQ variations of estuary pollution due to natural or anthropogenic inputs of point and non-point sources. Moreover, pollutants entering an estuarine system normally result from many transport pathways including discharge from ditches and creeks, storm water runoff, groundwater seepage, vadose zone leaching and atmospheric deposition [18]. Descriptive statistic was conducted to describe and to compare the selected physicochemical parameters in Semerak River estuary. The summary of descriptive analysis can be seen in Tables 3. Most of the variables had wide ranges which are emphasize the heterogeneity of the estuary system and the multiplicity and variability of pollutant sources along sampling points. The standard deviation for each MWQ parameters signifies the mean variation from the average for each MWQ parameters. A high standard deviation indicates that the data is widely spread, because of the existence of temporal variations caused likely by natural and/ or anthropogenic polluting sources [19]. Temperature for both estuary was always homogeneous within the studied areas. Having a tropical rainforest climate setting, the water temperature varies from 26 to 34 °C for Semerak River estuary. Mean value of pH for the estuary was in good condition (pH 6.8 to 7). Salinity values showed a wide range of variation because of sampling point distance. The mean value of TDS and COND were 7444 mg/L, 12564 mS cm^{-1}. The results indicate that there were no significant variations on physico-chemical parameters of water along the sampling activity.

There are several MWQ parameters are above permissible limit according to Class E (Mangrove estuarine and river mouth water) from Malaysia Marine Water Quality Criteria and Standards [16]. In consequence, the MWQ parameters in study areas are still in controlled conditions. However, there are several MWQ parameters are exceeding the MWQ permissible limit. In Semerak, NH_3N, PO_4, NO_3 and O&G are surpassed the permissible limit. The upsurge rate of nutrients for Semerak River estuary could be due to the influx of anthropogenic inputs and waste discharge containing nitrogen and phosphorus compounds from surface runoff to the estuary [20].

Table 3: Descriptive Statistics of the physico-chemical parameters in Semerak River estuary.

Statistic	TEMP (°C)	pH	SAL (%)	TDS (g l-1)	Cond (mS cm^{-1})	DO (mg/L)	NH_3N (mg/L)	TSS (mg/L)	Faecal Coliform (count/100ml)	PO_4 (mg/L)	NO_3 (mg/L)	O&G (mg/L)	MWQI
Minimum	26.600	3.560	0.940	110	1931	2.010	0.000	0.000	0.033	0.000	0.000	0.022	41.701
Maximum	32.600	9.900	18.130	19214	33377	7.750	2.350	26.400	154.790	0.771	1.574	0.214	97.315
1st Quartile	28.300	6.518	6.118	8091	14582	3.430	0.080	0.148	0.970	0.064	0.010	0.072	63.884
Median	29.200	7.270	10.895	12808	21490	4.180	0.190	1.050	4.501	0.183	0.064	0.103	71.880
3rd Quartile	29.725	7.660	15.325	16465	27967	5.010	0.810	3.125	32.727	0.209	0.362	0.147	81.935
Mean	29.404	6.791	10.787	12075	20961	4.261	0.549	2.916	24.041	0.187	0.258	0.112	72.653
Variance (n-1)	2.325	2.215	25.718	28917010	71059425	1.430	0.478	24.622	1299.636	0.025	0.134	0.003	206.750
Standard deviation (n-1)	1.525	1.488	5.071	5377	8430	1.196	0.691	4.962	36.050	0.158	0.367	0.051	14.379
Permissible Limit (Class E)	≤ 2	NA	NA	NA	NA	4	0.07	100	100	0.075	0.055	0.14	NA

3.1. Analysis of Variance (ANOVA) for MWQI

The mean of MWQI for Semerak River estuary was 66.00. Thus, this estuary was classified as Moderate (50<80) according to Marine Water Quality Index Classification [16]. Fig. 2 shows the MWQI for Semerak River estuary in box and whiskers plot. For describing the changes, to validate the achievement of the experiment and give the correct conclusions to MWQI, one-way ANOVA with post hoc Tukey HSD (Honest significant difference) has been applied to the sampling data for each sampling point to have the statistical significance test.

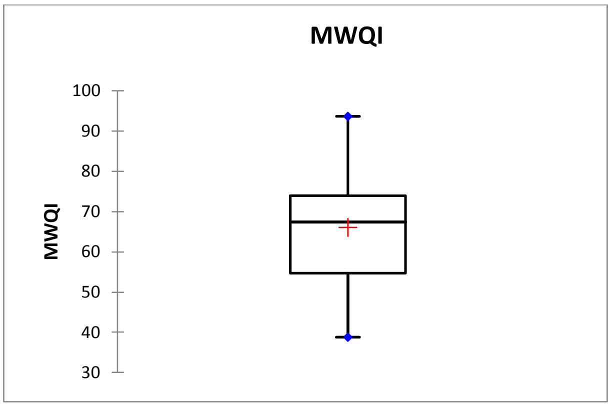


Fig. 2: Box and whiskers plot for MWQI in Semerak River estuary

The p-value corresponds to the F-statistic of one-way ANOVA is lower than 0.05 in the study area (Table 4), strongly suggested that one or more pairs of treatments are significantly different. In some cases of the Tukey HSD test, the p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05 which strongly suggests that one or more pairs of treatments are significantly different. Here, the present study used k = 2 treatments, for which one shall apply Tukey's HSD test to each of the one pair to pin-point which of them exhibits statistically significant difference.

Table 4: Analysis of Variance for MWQI in Semerak River estuary's sampling station.

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	3643.772	728.754	5.521	**0.000**
Error	102	13464.529	132.005		
Corrected Total	107	17108.301			

Firstly, the critical value of the Tukey–Kramer HSD was established for significance level 0.05 (p-values) in the Studentized Range distribution. The results obtain these critical values for sampling stations at Semerak River estuary, for as 4.1080 (Table 5).

Table 5: Station / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95% (MWQI) in Semerak River estuary.

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant
SM2 vs SM5	15.035	3.926	2.905	**0.002**	Yes
SM2 vs SM4	13.161	3.437	2.905	**0.011**	Yes
SM2 vs SM6	9.798	2.558	2.905	0.117	No
SM2 vs SM1	3.012	0.786	2.905	0.969	No
SM2 vs SM3	1.777	0.464	2.905	0.997	No
SM3 vs SM5	13.258	3.462	2.905	**0.010**	Yes
SM3 vs SM4	11.385	2.973	2.905	**0.042**	Yes
SM3 vs SM6	8.021	2.095	2.905	0.298	No
SM3 vs SM1	1.235	0.323	2.905	1.000	No
SM1 vs SM5	12.023	3.139	2.905	**0.026**	Yes
SM1 vs SM4	10.149	2.650	2.905	0.095	No
SM1 vs SM6	6.786	1.772	2.905	0.488	No
SM6 vs SM5	5.236	1.367	2.905	0.746	No
SM6 vs SM4	3.363	0.878	2.905	0.951	No
SM4 vs SM5	1.873	0.489	2.905	0.996	No

* *Tukey's d critical value: 4.1077*

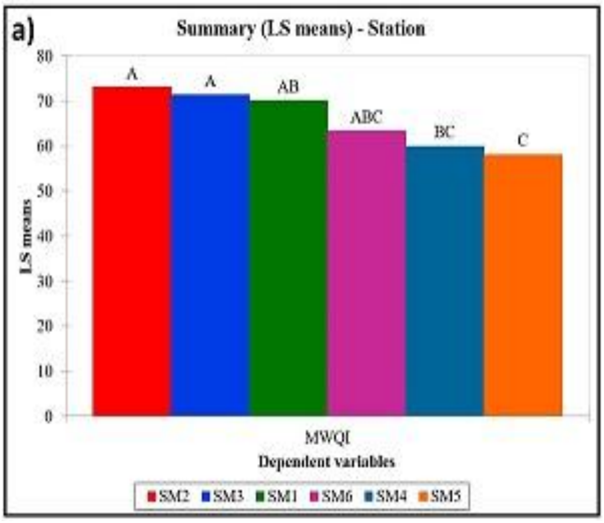
Post-hoc Tukey HSD test calculates by evaluating whether MWQI for SM1 is more than the critical MWQI value for all relevant pairs of treatments. The test is also performed by using studentized range distribution as well as p-values corresponding to an observed value of MWQI. The statistics in Table 6 concludes that even though the MWQI for SM1 is somewhat better accuracy than others, still it is not that much significant to outweighs the other.

Table 6: Station / Tukey (HSD) / Analysis of the differences between the categories with a confidence interval of 95 % (MWQI).

Estuary	Category	LS means(MWQI)	Groups		
Semerak	SM2	73.138	A		
	SM3	71.361	A		
	SM1	70.126	A	B	
	SM6	63.339	A	B	C
	SM4	59.976		B	C
	SM5	58.103			C

As a consequence, the present study found the following MWQI for sampling stations in both estuaries have slightly different value because of variability of MWQ concentrations. Likewise, both estuary have same common of pollution source. It is well understood that MWQI for Semerak River estuary results in low accuracy in comparison to sampling stations. To get the better understanding of post hoc tests, Table 6 indicates the summary of all pairwise comparison for all stations in Semerak River estuary. In combinations that include MWQI, SM1, SM2, SM3 and SM6 share the same letter (A) and have no letter with SM4 and SM5 which also share the same letter (C). This means that the two groups of stations not significant on MWQI.

Fig. 3 signify Least Significant (LS) means for all station. LS means tool, which is useful to match the effects of the same set of factors and interactions on different dependent variables. The LS means chart is associated to every factor and interaction. For the spatial factor at sampling stations, the LS means summary chart displays estimations of the mean MWQI of every stations for each of the two dependent variables. The chart shows that, notwithstanding of the MWQI, stations mostly not significant, which is supported by p-values associated with the stations effects in ANOVA model. While comparing with others existing research, statistical significance test along with post hoc tests inhibits deeper understanding to choose the best model out of many.



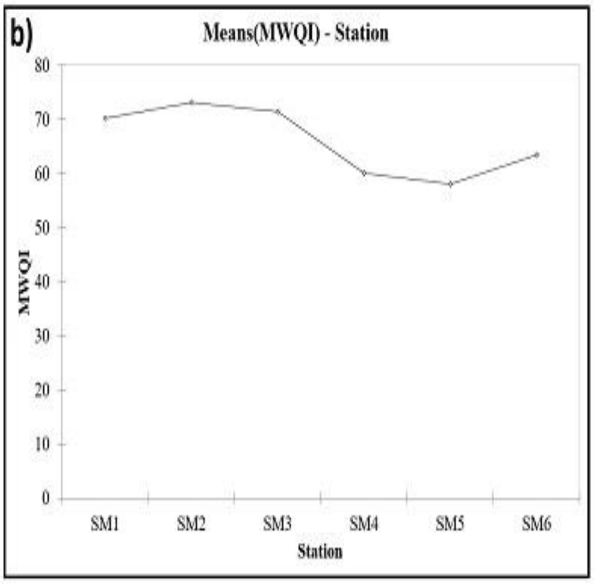


Fig. 3: a) LS and b) means chart for Semerak River estuary

3.2. Temporal variations and spatial distribution for physico-chemical parameters

On a seasonal scale, the DO values show a wide range of variation for the estuary. Fig. 4 showed the comparison of SWM and NEM using box and whiskers plot for seven main parameters in Semerak River estuary. The mean value of DO concentration during SWM for SM (4.51 mg/L) give a better concentration than DO values during NEM (3.44 mg/L), respectively (Fig. 4). According to Barakat et al. [21], the water temperature was indeed significantly lower in dry season than wet season which may be the main benefactor leading to the observably higher DO concentration in dry season than wet season. In Semerak River estuary, DO value ranging from 1.96 mg/L to 7.10 mg/L during SWM and 2.00 mg/L to 5.12 mg/L during NEM. Permissible Limit of Malaysia Marine Water Quality Criteria and Standards for DO is 4 mg/L. From the result, DO concentration during NEM is below the permissible limit. From Fig. 5**,** there are no significant different of DO concentration between each sampling station both SWM and NEM. When DO values is greater than 4.00 mg/L indicating that surface waters are moderately oxygenated [22], while low DO values (less than 2.00 mg/L) would indicate poor water quality and thus would have difficulty in sustaining many sensitive aquatic life in estuary.

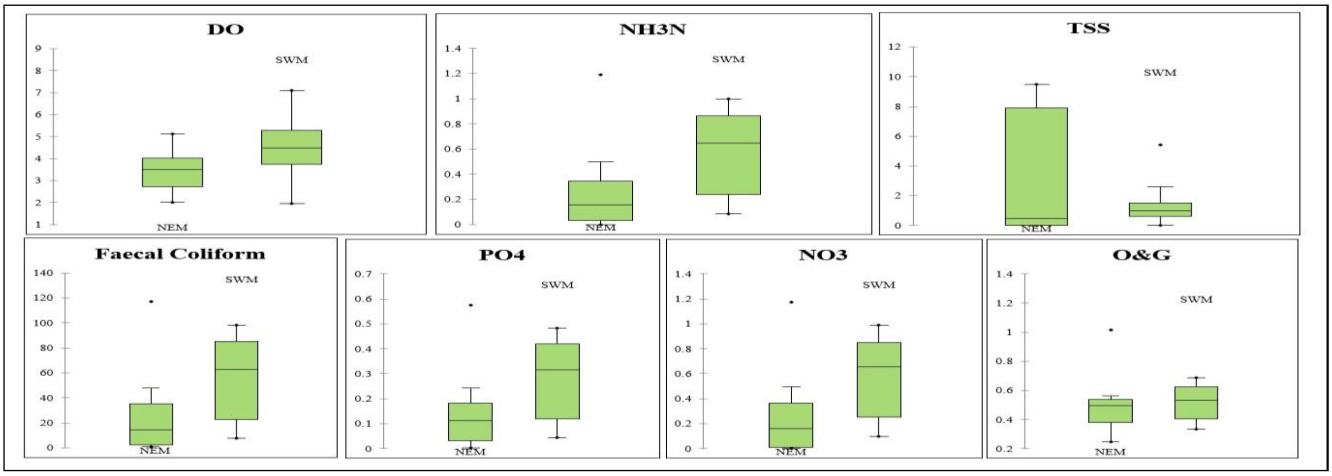


Fig. 4: Comparison of SWM and NEM in Semerak River estuary.

DO plays a vital role in every aquatic system and its variation always depends upon the photosynthesis, degradation of organic matter and some chemical reaction [23, 24]. The main reason DO levels might fall in study areas are the occurrence of organic waste coming from raw or poorly treated sewage, farm and feedlots runoff and natural sources (i.e. decaying aquatic plants and animals and fallen leaves in water). Thus, more oxygen being used for decomposition process. This situation is supported by [25], the reason for low DO level is caused by the high discharge of organic pollution and nutrient along the mangrove estuary which will usually upsurge respiration during organic matter degradation.

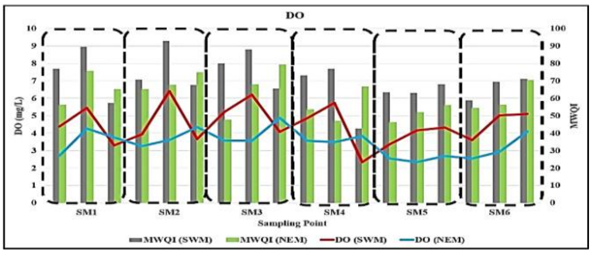


Fig. 5: Comparison of DO concentration.

Based on Fig. 4, the mean of faecal coliform for Semerak River estuary during SWM (54 count/100 ml) and NEM (23 count/100 ml), respectively. Maximum value of faecal coliform reach 98 count/100 ml. Faecal coliform is countable in each sampling station (SM1 to SM6) Semerak River estuary (Fig. 6**).** Fortunately, faecal coliform is below permissible limit of Malaysia Marine Water Quality Criteria and Standards (100 count/100 ml) for both monsoon. The presence of these indicative organisms is evidence that the water has been polluted with faeces of humans or other mammals. From the result, the source of faecal coliform mostly from untreated sewage, poorly maintained home-septic systems and faeces from animal husbandry with contact to water body. O&G concentration in Semerak River estuary is 0.523 mg/L during SWM and 0.491 mg/L during NEM (Fig. 4). From the result, O&G concentration in Semerak River estuary has surpass the permissible limit of Malaysia Marine Water Quality Criteria and Standards (0.140 mg/L). This is believed that the nonpoint source from fishery boats is major contribute to the high concentration of O&G in Semerak River estuary, especially in SM1 and SM4 (Fig. 7).

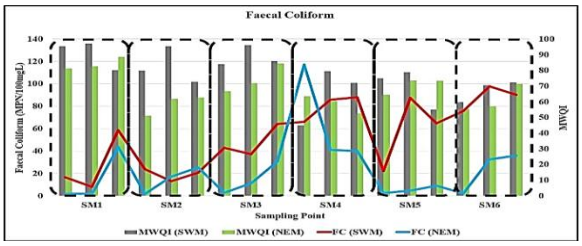


Fig. 6: Comparison of Faecal Coliform concentration.

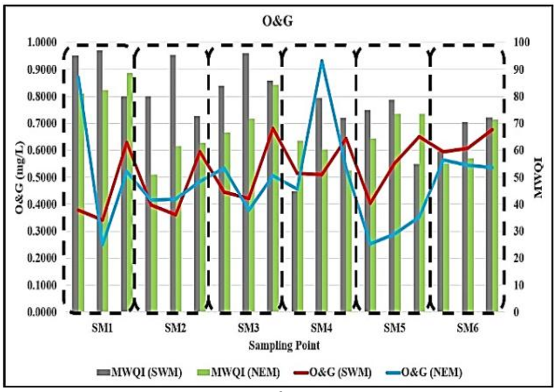


Fig. 7: Comparison of O&G concentration.

The mean value of TSS concentration is quite low in Semerak River estuary (SWM: 1.281 mg/L, NEM: 2.916 mg/L) as shown in Fig. 4 and Fig. 8. This suggests that there was no heavy erosion taken place along the study areas [23]. TSS shows higher concentration if more sediment was washed into stream by erosion and deposition processes [25]. High contents of TSS may decrease the transparency of water body, resulting in depletion of DO, also prevent sunlight to penetrate into water and then affected the estuary water quality [21].

In fact, TSS in the study areas is far below permissible limit of Malaysia Marine Water Quality Criteria and Standards for Class E (100 mg/L). Many pollutants mostly toxic heavy metals can be attached to TSS, which is not good for the aquatic habitat and lives. The series of sediment-induced changes that can happen in a water body may alter the composition of an aquatic community. As a consequence, overall aquatic species may also decline, which may then lead to decreased fish populations.

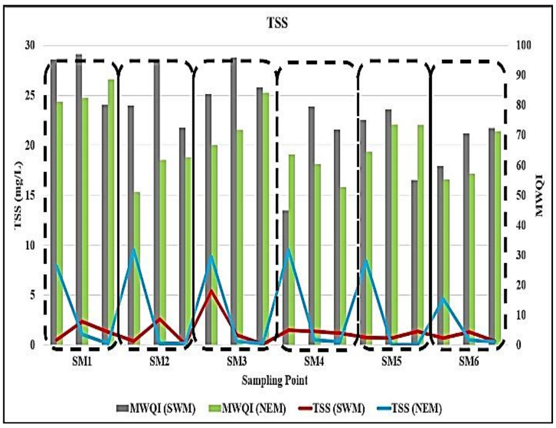


Fig. 8: Comparison of TSS concentration.

Nutrients such as NH_3N, NO_3 and PO_4 has been measured in Semerak River estuary. From the results, the concentration of nutrients did not show distinct difference between SWM and NEM. Based on [26], the increased runoff and erosion induced by greater rainfall intensities could lead to an increase in nutrients transport especially particulate phosphorus. This is supported by Shigaki et al. [27], said, there is also a link between nutrients runoff from agricultural fields and freshwater eutrophication. Fig. 9 shows the comparison of NH_3N concentration during SWM and NEM in the study areas. In Fig. 4, concentration of NH_3N for both monsoon in Semerak River estuary (0.549 mg/L, 0.234 mg/L) exceeded permissible limit of Malaysia Marine Water Quality Criteria and Standards (0.07 mg/L). Besides, NO_3 concentration during SWM and NEM in Fig. 10 (0.555 mg/L, 0.239 mg/L) and PO_4 concentration during SWM and NEM in Fig. 11 (0.268 mg/L, 0.128 mg/L) also exceeded permissible limit of Malaysia Marine Water Quality Criteria and Standards (0.06 mg/L, 0.075 mg/L), respectively. According to Fig. 9, Fig. 10 and Fig. 11, the distribution of these parameters is significantly dominant and high at SM4, SM4 and SM6. This means the distribution of nutrients are generally abundance at downstream of the estuary. This may be attributed to increased nutrients, possibly in response to vertical salinity stratification and low dissolved oxygen that foster regeneration of nutrients from bottom sediments [28].

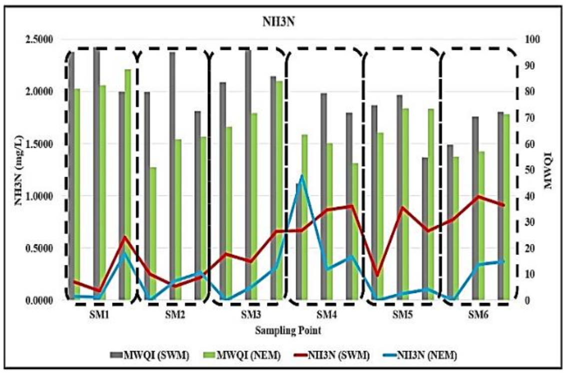


Fig. 9: Comparison of NH_3N concentration.

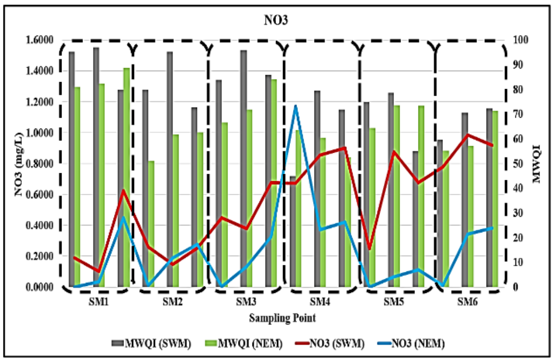


Fig. 10: Comparison of NO_3 concentration.

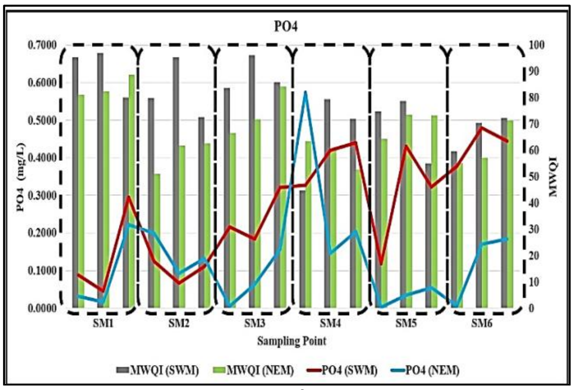


Fig. 11: Comparison of PO_4 concentration.

Based on the study areas, a possible explanation of occasional increases in nutrient concentration was caused by the presence of strong currents in agriculture activity, animal husbandry and fish farming areas. The presence of nitrogen and phosphorus originated from both point source and non-point sources such as anthropogenic activities, soil erosion, water runoff from cropland, agro based industries (prawn processing units) and small livestock confinement operation [28, 29, 30]. As with salinity, the limited strength of the higher low tide gave higher concentrations of nutrients. According to Shigaki et al. [27] the source of phosphorous for estuary may be from surface run-off and its autochthonous origin during monsoon. Besides, higher levels of nutrients were observed in the mangrove areas as these environments are rich sources of organic matter [24]. Overall, the variation of nutrients showed seasonal and spatial changes along the study areas. The different climate and rainfall between SWM and NEM seasons may affect the distributions of nutrients contents [18].

4. Conclusion

A case study was done successfully and well-discussed in this study which was an assessment of spatial distribution and temporal variation analysis for MWQ parameters in Semerak River estuary. Univariate analysis was used in determined the MWQ parameters for the spatial and temporal. The results showed that the possible pollution sources in this estuary coming from major agriculture influenced, fertilizers, fishing boat and sand mining, natural environment from weathering of geologic sources, surface runoff and oil-spill from fishing boat.

It is recommended that the related agencies should take actions to control all these sources of pollution in order to improve the water quality in this estuary. Laws and regulations can be enforced in a much stricter way to make sure there is no any abuse of the environment. Hence, long term monitoring need to be undertaken to ensure the water quality for mangrove estuary will not degrade and that the health of mangrove ecosystem is sustainably conserve. In addition, this paper hopefully could contribute towards more effective marine water quality in mangrove estuary management

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