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RESEARCH ARTICLE

A preliminary study of marine water quality status using principal component analysis at three selected mangrove estuaries in East Coast Peninsular Malaysia

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Abstract

This research presents marine water quality status in three different mangrove estuaries. The objective of this study is to evaluate the surface water quality of three estuaries in east coast Peninsular Malaysia. The parameters measured were Dissolved Oxygen (DO), pH, Biochemical Oxygen Demand (BOD), Salinity (SAL), total dissolved solid (TDS), ammonium (NH_4-N), turbidity (TUR), total suspended solid (TSS) and coliform. Monthly sampling was performed during the dry season, from June 2016 until September 2016. Data were analysed using principal component analysis (PCA). PCA yielded two PCs where VF1 forms strong factor loadings for pH, NH_4-N, SAL, and TDS signifying saltwater intrusion in mangrove area. VF2 designed strong factors of BOD, TUR and Coliform and strong negative loading of DO indicating anthropogenic pollutions in the area. This study output will be a baseline setting for future studies in mangrove estuary marine water quality. Mangrove 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.

Keywords: Marine water quality, Mangrove, Estuaries, South China Sea, Principal component analysis

INTRODUCTION

Mangrove is known as a unique, and endangered, coastal ecosystems that plays a vital role in tropical and subtropical regions, located in the intersection between land and sea (Holguin *et al*. 2001). This ecosystem acts as a buffer area being essential for maintaining the sea level and for protecting the coast (Duke *et al*. 2007). Mangrove habitats also function as sinks for ensnaring heavy metals under normal circumstances. The mangroves will become an inception for discharge of pollutants once the habitats are disturbed by natural disaster or human activities. Pollution and destruction of mangrove forest can also affected river water quality. Reported negative impacts of mangrove loss include reducing marine water quality, eradicating fish nursery habitats, decreasing biodiversity and affecting adjacent coastal habitats (Mumby, 2004). In addition, mangrove loss might affect tourism income for the country and demolition of the associated mangrove ecosystem especially flora and fauna (Sandilyan and Kathiresan, 2014). The interaction of ground water and surface water that was affected by human activities and natural process may cause unfavorable aquatic environment and the water can receive pollution load naturally without decreasing in quality (Kumar and Murty, 2011). However overflow of pollutant that reaches any water bodies' maximum capacity is dangerous to living organism. Common changes may occur due to natural phenomena (dissolution, precipitation and sorption) during heavy metal transportation in the riverine system. Mangrove forest shows decreasing biodiversity resulting from ecosystem disturbance (Hauff *et al.* 2006). Due to the increasing human population, the exploration of mangrove forest through human activities such as logging activities, deforestation, agricultural land, aquaculture activity and industrial waste gives negative environmental impact especially to water quality of mangrove forest (Hauff *et al.* 2006). Thus, water quality measurement is compulsory for managing safe and reliable water sources. Poor water quality is harmful to living organisms and the ecosystem. Given these environmental issues, several studies have been done on monitoring marine water quality in mangrove areas, exclusively to give comprehensive picture of the forces acting on mangrove ecosystem. Some examples related to this research include the mangrove swamps of Ariyankuppam estuarine complex, Pondicherry, India (Satheeshkumar and Khan, 2012), Port Dickson, Malaysia (Praveena and Aris, 2013), and Upper Merbok Estuary, Kedah, Malaysia (Ismail and Ibrahim, 2015). This work is the first preliminary study to evaluate the surface water quality of three mangrove estuaries in east coast of Peninsular Malaysia (Semerak Lagoon, Setiu Wetland and Merang Estuary).

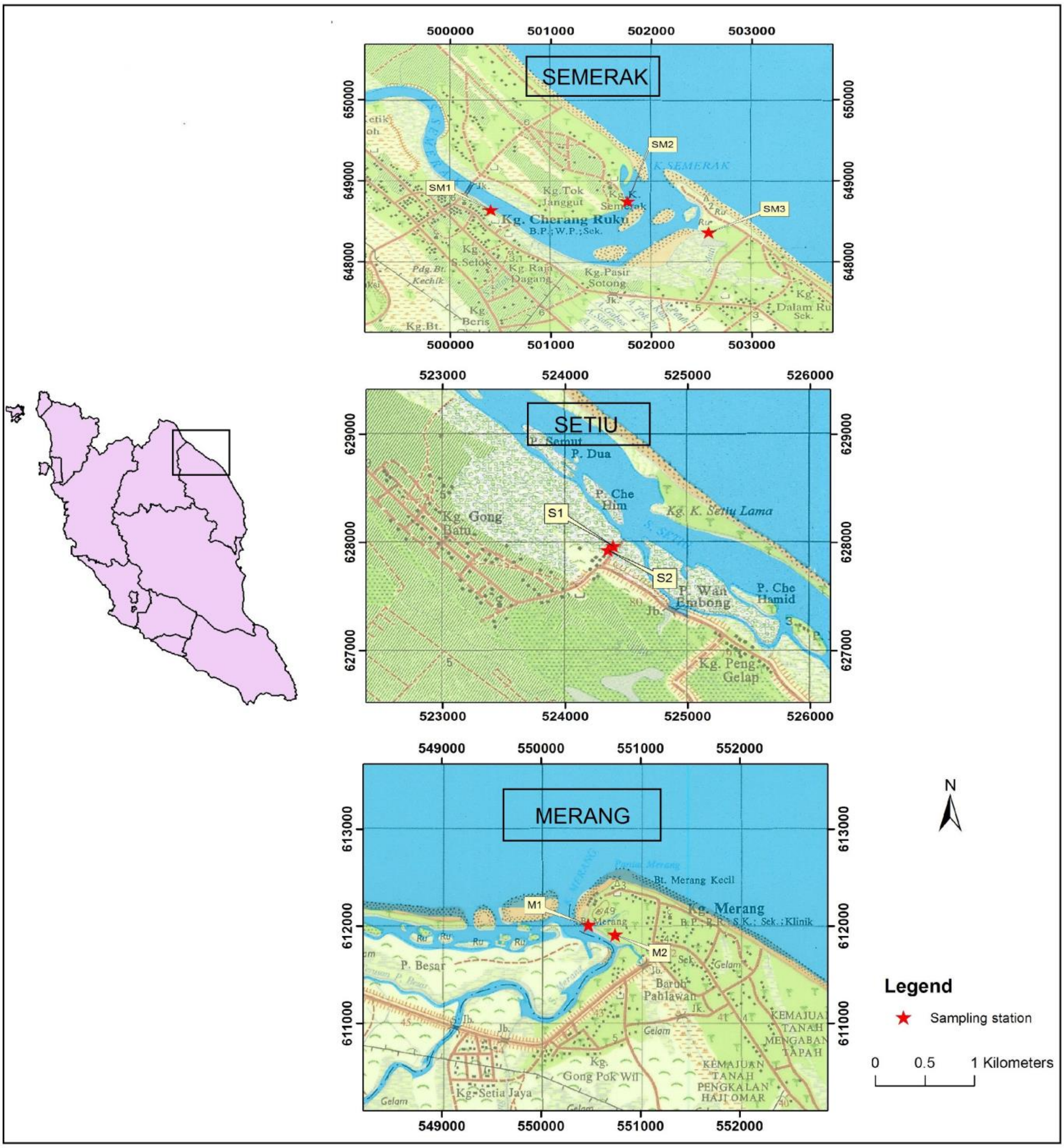

Fig. 1 Locations of sampling stations

EXPERIMENTAL

Study Area

Water samples were collected in June 2016 until September 2016 during dry season at three sampling stations in Semerak Lagoon, two sampling stations in Setiu Wetland and two sampling stations at Merang river estuary (Fig. 1). All these station situated at east coast of peninsular Malaysia facing the South China Sea. Semerak lagoon is originated from Semerak River Basin which is semi-enclosed lagoon with a total area 1.7 km2 with an average depth of 3.12m located in Pasir Puteh, Kelantan. This lagoon contain 5,304,000m² water during high tide (Shaari *et al.* 2015). Setiu wetland and Merang estuary situated at Setiu district, Terengganu. Merang River Basin with 39,115,835.46m ² immensity is the shortest river basin in Setiu district (8km) with catchment area km². Setiu River Basin has catchment area 188 km² approximately and is 52km long and 148,535,660.9m² immensity (DID, 2014). Setiu Wetland covers 23,000 ha area and the water column is well mixed and shallow (Suratman *et al*. 2016).

Table 1. Information of monitoring stations.

Station	Latitude	Longitude	Description
SM1	5°86'50.50"N	102°49'40.00"E	Semerak Lagoon
SM2	5°86'60.32"N	102°50'62.95"E	Semerak Lagoon
SM3	5°86'25.74"N	102°51'35.70"E	Semerak Lagoon
S1	5°67'83.80"N	102°.71'07.60"E	Setiu Wetland
S2	5°67'80.40"N	102°71'03.70"E	Setiu Wetland
M1	5°53'43.40"N	102°94'62.70"E	Merang Jetty
M2	5°53'34.30"N	102°94'87.00"E	Merang Jetty

Sample collection and preparations

The water quality parameters selected in this study refers to the Marine Water Quality Index (MWQI) (DOE, 2015) as a guideline which include dissolved oxygen (DO), pH, biochemical oxygen demand (BOD), Salinity (SAL), total dissolved solids (TDS), ammonium (NH_4-N), turbidity (TUR), total suspended solid (TSS) and coliform. Water sampling were conducted during high and low tides and collected from subsurface water into 1L high density polyethylene (HDPE) bottles prewashed with dilute hydrochloric acid (10%) and rinsed three times with water sample. The samples were stored at 4°C and were transferred to the laboratory for analysis. Water sampler was used to collect water samples on the spot for detecting physico-chemical parameters. In situ measurements such as DO, SAL, TDS, pH, NH_4N, TUR, and BOD were performed using YSI Multi Parameter Water Quality Sonde, Modern Water BODChek and HACH Turbidity Meter. TSS were analysed in the laboratory using a method by APHA (APHA, 1998). The TSS was calculated using gravimetric method which based on the weight of the filter after samples were filtered (0.45µm filters, Milipore) and dried at room temperature within 24 hours. Coliform was calculated using 1 ml of fresh water sample which was pipetted on 3M™ petrifilm plates. The samples were incubated for 18 hour at 37°C (APHA, 1998).

Statistical analysis

Statistical analysis was performed using XLSTAT 2014 software. The box plot is a visualizing data which represent the descriptive statistics of the data set. The famous ‘stem and leaf diagram’ in box plot are representing data semi graphically (Tukey, 1990). Besides, the ANOVA Single Factor was used to reveal the significant value of each water quality parameter at the 95% confidence level (a = 0.05).

Principal component analysis

Purposely, Principal Component Analysis (PCA) was used to reduce the number of variables and to detect structure in the relationship among the variables. PCA also signifies the most significant parameters by exhibiting the source of variation that has been depicted from the whole data set. In this approach, the less significant variables were omitted from the whole data set with a very minimum loss of its original information in the analysis. Principally, the varimax rotations applied to PCs with eigenvalues more than one are considered significant in obtaining new groups of factors known as varimax factors (VFs) (Dominick *et al*. 2012; Vega *et al*. 2011; Juahir *et al*. 2004).

RESULTS AND DISCUSSION

Figure 2 shows the distribution of marine water quality parameters. The ranges of parameters in all stations were recorded. Based on Table 2, ANOVA shows significant difference ($p<0.05$) for all parameters between Semerak, Setiu Wetland and Merang. This can be strengthened further by box and whiskers plot in Fig. 2.

Table 2 Anova Single Factor.

Parameter	*F*	*P-value*	*F crit*	*Average*	*Std. Deviation*
DO	26.18	0.00	3.18	3.09	0.88
BOD	17.61	0.00	3.15	1.36	0.44
pH	21.53	0.00	3.16	7.16	0.50
NH_4-N	34.87	0.00	3.18	53.53	22.32
SAL	26.72	0.00	3.16	16.68	4.81
TUR	27.88	0.00	3.28	15.13	6.94
TSS	11.53	0.00	3.32	40.03	22.57
TDS	31.85	0.00	3.16	17994.35	5177.66
Coliform	11.39	0.00	3.32	182.90	64.96

*One-way Anova Single Factor shows significant different between each marine water quality parameters ($p > 0.05$).

The highest DO concentration average was recorded at Semerak while Setiu has the lowest concentration average of DO. Decrease of DO content caused by the presence of pollutants such as heavy metals in that area (Fashchuk. 2011). Four out nine parameters (BOD, TUR, TSS and Coliform) show Setiu Wetland gives the highest concentration average of parameters than Semerak and Merang. Salinity and pH for Merang show the highest value because of the M1 and M2 located in river mouth of the Merang River. Futhermore, pH, NH_4-N and TDS also give the highest concentration average for Merang, due to the same condition. Semerak Lagoon. Based on the findings, Setiu Wetland is more polluted than Merang and Semerak according to Class E of the Marine Water Quality Standard and Criteria (DOE, 2015). Recently, several studies in Setiu Wetland has been reported. Agricultural (oil palm plantation) and aquaculture activities (cage culture, pen culture, oyster farming and pond culture) are the core dubious factors which are changing the fresh water inputs to the wetland (Koh *et al*. 2015; Suratman *et al*. 2014; Kamaruzzaman *et al*. 2009).

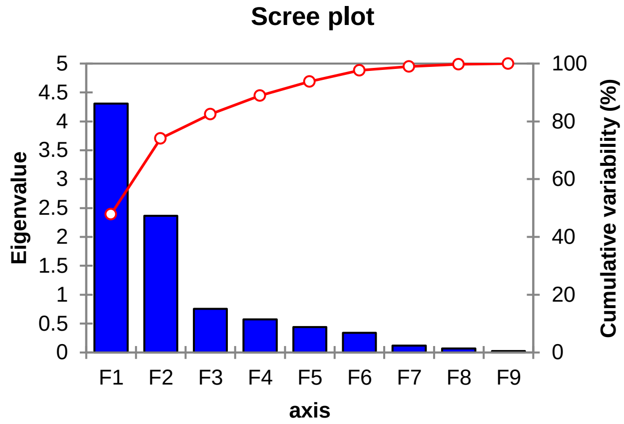

Fig. 3 Scree plot of eigenvalues.

Scree Plot in Figure 3 shows eigenvalues from PCA. Eigenvalues of the correlation matrix which represent a partitioning of the total variation accounted for each principal component. This is a plot of the eigenvalues associated with each of the factors extracted, against each factor. At the point that the plot begins to level off, the additional factors explain less variance than a single variable. There are two factors which eigenvalues more than 1 (4.3077 and 2.364). These two factors indicate two rotations in PCA. That means, nine marine water quality parameters were reduced to two factors.

Table 3 presents factor loadings after varimax rotation (according to eigenvalues). PCA of the entire data set (Table 3) involved two principal components with eigenvalues greater than one explaining about 74.13% of the total variance in the water-quality data set. VF1 shows 47.86% of total variance for pH, NH_4-N, SAL, and TDS. This varimax factor represents the saltwater intrusion into river mouth of mangrove area due to high salinity in estuary condition (Hairoma *et al*. 2016). The presence of NH_4-N was caused by anthropogenic activities and manure from livestock. As with salinity, the limited strength of the higher low tide gave higher NH_4-N concentrations (Wong *et al*. 1995). Biplot chart in Fig. 4 represents the water quality parameters simultaneously in the new space. Which shows VF1 linked with M1 and M2 station. VF2 presents 26.27% total variance of strong positive loadings of BOD, TUR and Coliform and strong negative loading of DO. This VF represents the anthropogenic activities that is linked to agriculture and aquaculture (Suratman *et al.* 2014). High BOD concentration influences of bad water quality which is caused by aquaculture activities. the strong significant correlation caused by the high levels of dissolved organic matter that will unavoidably deplete large amounts of oxygen hence reducing the levels of DO required in brackish water at the mangrove estuary (Vega *et al*. 2011). Besides, this result was reliable with the previous study which said the high levels of organic matter from aquaculture discharged originating from conceiving from faeces, organic fertilizer and feedstuff (Hairoma *et al*. 2016; Koh *et al*. 2015; Suratman *et al*. 2014; Alongi *et al*. 2009; Wong *et al*. 1995;).

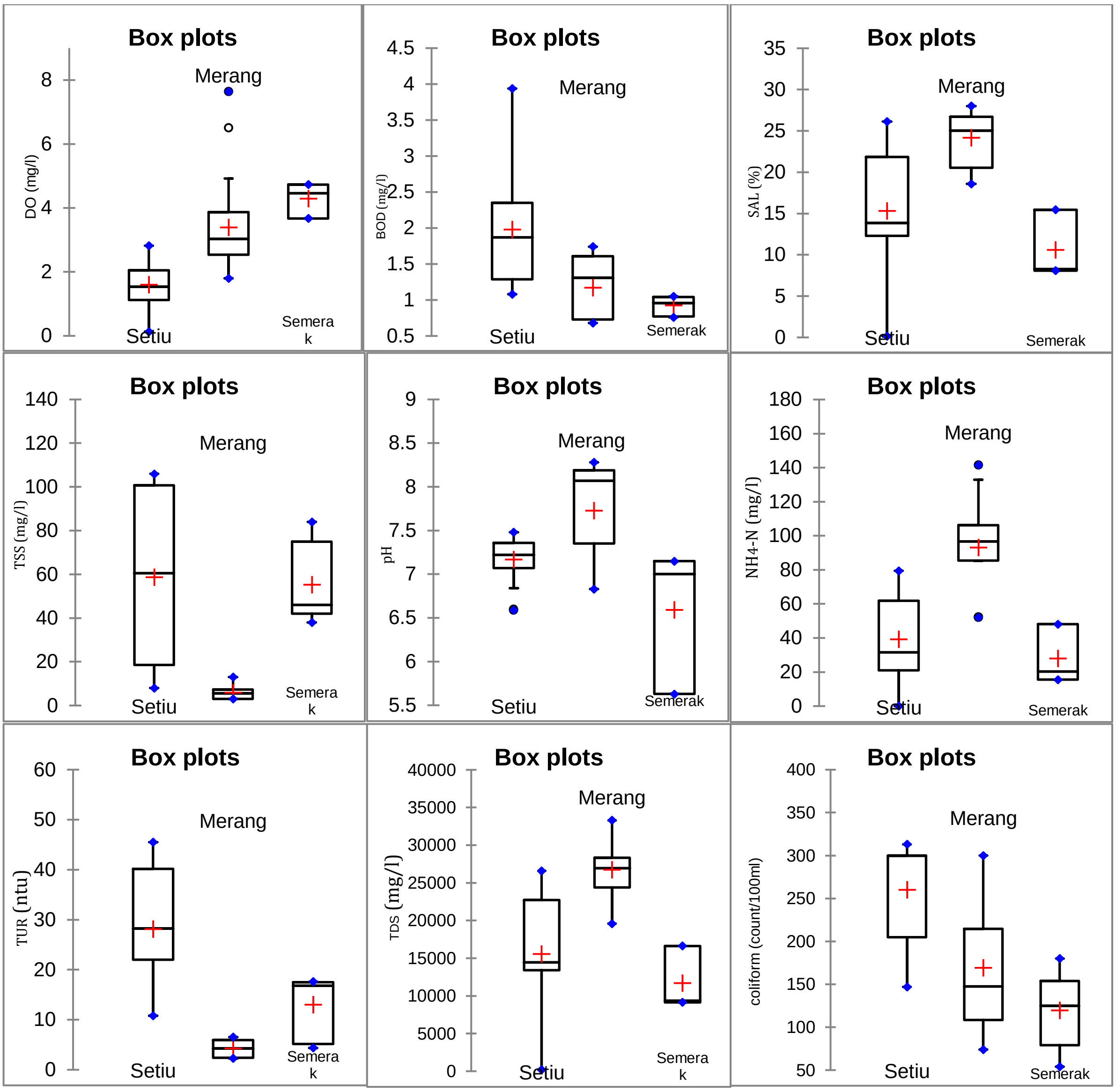

Fig. 2 Box plot of water quality parameters measured.

Table 3 Factor Loading after varimax rotation

	VF1	VF2
DO	0.1895	**-0.8015**
BOD	0.0395	**0.7960**
pH	**0.7344**	-0.2339
NH_4N	**0.9146**	-0.3060
SAL	**0.9566**	-0.0833
TUR	-0.5369	**0.7284**
TDS	**0.9062**	0.0154
TSS	-0.6088	-0.3982
Coliform	-0.0697	**0.8589**
Eigenvalue	4.3077	2.3640
Variability (%)	47.8635	26.2671
Cumulative %	47.8635	74.1306

The presence of coliform which is caused by faecal waste also suspected to be originated from the same point source pollution (Mohd *et al.* 2011). Based on Fig. 3, S1 and S2 are included in VF2. Interestingly, SM1, SM2 and SM3 are not in any VF because of the significant differences in water quality compared to the other stations. Thus, Semerak Lagoon is considered as having good quality of water compared to Setiu Wetland and Merang estuary.

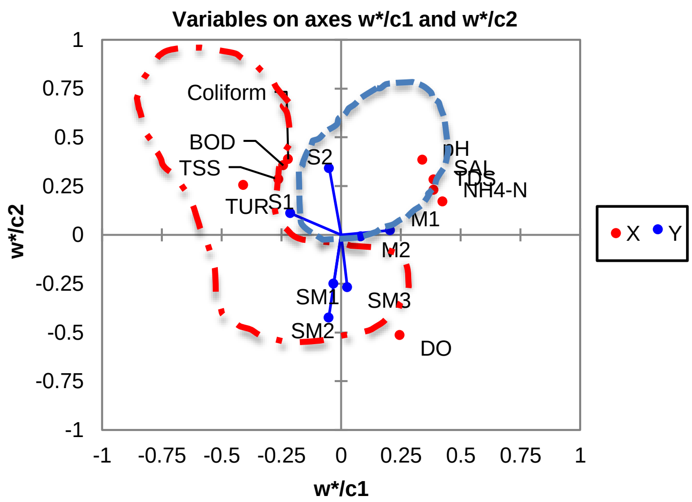

Fig. 3 Biplot chart after varimax rotation.

- Biplot chart in figure 3 shows VF2 linked with S1, S2, SM1, SM2 and SM3 station.

CONCLUSION

This is the preliminary study reassessment of marine water quality status of mangrove estuary at selected area in the east coast of peninsular Malaysia. This study consist of three mangrove estuary areas (Semerak, Setiu and Merang) which were chosen based on lack of water quality status studies in mangrove ecosystems which act as a baseline study in marine water quality at estuary for the future research. From the finding of PCA, the pollution apportionment from these three areas which affect marine water quality status include saltwater intrusion and anthropogenic activities. The outcomes show that Semerak lagoon has good marine water quality status compared to Setiu Wetland and Merang estuary. Hence, long term monitoring for these areas 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. Future study should focus on developing a workable water quality modelling as exquisite tool to simulate marine water quality and forecast future consequences which will help mangrove biodiversity conservation.

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