Marine Pollution Bulletin 67 (2013) 196–199

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

A baseline study of tropical coastal water quality in Port Dickson, Strait of Malacca, Malaysia

Sarva Mangala Praveena [a], Ahmad Zaharin Aris [b,*]

[a] Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[b] Environmental Forensics Research Centre, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

ARTICLE INFO

Keywords:
Coastal water
Nutrients
Physicochemical properties
Pollution
Baseline

ABSTRACT

Tidal variation in tropical coastal water plays an important role on physicochemical characteristics and nutrients concentration. Baseline measurements were made for nutrients concentration and physicochemical properties of coastal water, Port Dickson, Malaysia. pH, temperature, oxidation reduction potential, salinity and electrical conductivity have high values at high tides. Principal Components Analysis (PCA) was used to understand spatial variation of nutrients and physicochemical pattern of Port Dickson coastal water at high and low tide. Four principal components of PCA were extracted at low and high tides. Positively loaded nutrients with negative loadings of DO, pH and ORP in PCA outputs indicated nutrients contribution related with pollution sources. This study output will be a baseline frame for future studies in Port Dickson involving water and sediment samples. Water and sediment samples of future monitoring studies in Port Dickson coastal water will help in understanding of coastal water chemistry and pollution sources.

Productivity potential of coastal water depends on nutrients distribution and behavior. Tidal variation in tropical coastal water greatly affects their physicochemical characteristics and nutrients concentration (Liu et al., 2011). Mixing of freshwater and seawater at high and low tides on hourly time scale determines strong changes of nutrients as well as physicochemical properties. Extent of changes will depend on tidal state and amplitude of coastal water (Gavio et al., 2010). A growing number of coastal water monitoring programs is crucial to collect huge datasets. Huge datasets are important to obtain a better understanding on how anthropogenic activities effect the coastal water environment. Huge datasets obtained from such monitoring programs require multivariate statistical methods. Principal Component Analysis (PCA) is one of multivariate statistical methods that used in interpretation and explanatory of huge datasets (Praveena et al., 2011a).

In the last 20 years, studies pertaining to nutrients (nitrate, phosphate, ammonia) have been reported along Port Dickson coastline, giving further impetus to studies on interactions between tidal and coastal water. Praveena et al. (2011b) concluded that comparison between dissolved organic phosphorus and ortho-phosphate levels indicated an increased in its concentration which clearly shows that major inputs of phosphorus sources occur in Strait of Malacca directly contribute to phosphorus concentration in Port Dickson water. Review done by Praveena et al. (2011b) also concluded that huge datasets on continuous and systematic of nutrients in Port Dickson coastal water have not been reported so far. Most of the investigations conducted on nutrients of Port Dickson coastal water were based as a single station in research projects. Thus, there is lack of understanding exists on tidal variations influence in nutrients and physicochemical properties in Port Dickson coastal water.

Here, this study aims to detect spatial variation of nutrients and physicochemical pattern of Port Dickson coastal water. In order to understand spatial variation of nutrients and physicochemical pattern of Port Dickson coastal water due to tidal variation (high and low tides), well known exploratory data analysis tool (Principal Component Analysis, PCA) was used. Output obtained in this study will provide baseline information on nutrient enrichments that can be used to identify hotspots which can direct future contaminants monitoring and management programs. Such baseline information can lead to reduce monitoring costs while simultaneously provide a better understanding of poor water quality causes.

This study took place in Port Dickson coastal stretch from north Tanjung Gemuk to south Tanjung Tuan facing the Strait of Malacca. Six sampling locations were selected where each sampling location has three transects parallel to the shoreline at 200 m, 500 m and 500 m to the sea (Fig. 1). Coastal water samples were collected from 18 sampling locations along Port Dickson coastline stretch facing the Strait of Malacca at high and low tides. Coastal water samples were collected in acid cleaned polyethylene bottles by using Van Dorn water sampler. In situ parameters (pH, oxidation

* Corresponding author. Tel.: +60 3 8946 7455; fax: +60 3 8946 7463.
E-mail address: zaharin@env.upm.edu.my (A.Z. Aris).

0025-326X/$ - see front matter
http://dx.doi.org/10.1016/j.marpolbul.2012.11.037

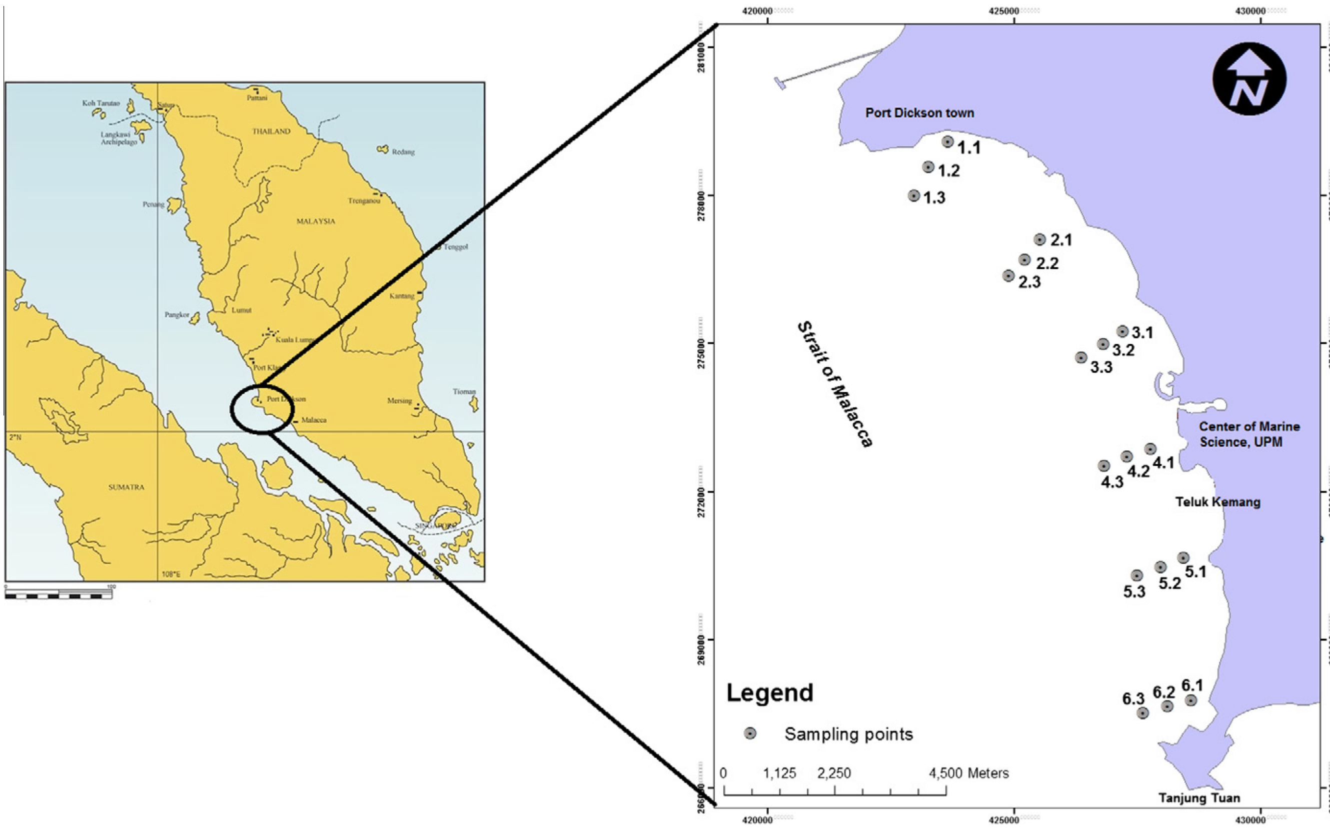

Fig. 1. Study area showing the sampling location.

reduction potential, temperature, salinity and electrical conductivity, Dissolved oxygen) were measured using WTW pH330i, YSI Model 32 and dissolved oxygen meter, YSI Model 52. All the meters were calibrated prior to sampling campaign. Turbidity measurement was done using a Sechhi disk. Dissolved nutrients (nitrate, phosphate and ammonia) and major ion (sulfate) were estimated using standard methods (APHA, 1995) by means of Hach – DR 2700 Portable Spectrophotometer. In order to obtain greater data confidence regarding bias and variability, appropriate quality control and assurance measures were implemented. Triplicate samples were collected to estimate variability resulting from the sampling and analytical procedures (APHA, 1995). Laboratory equipments were pre-cleaned with concentrated nitric acid (5%; v/v) and rinsed with distilled water. Equipment blank was used to test for bias from possible contamination of blank water which consists of distilled water. Equipment blank include total field and laboratory sources of contamination. Mean and standard deviation values were used as an indication of accuracy and precision of each parameter measured as well as analytical errors.

Statistical analysis (descriptive statistics) and principal component analysis were carried out for coastal water samples at high and low tides using SPSS ver. 17.0 statistical packages. Principal Component Analysis (PCA) using Varimax rotation was selected to understand spatial variation of the nutrients and physicochemical pattern of coastal water in Port Dickson due to tidal variation. PCA components above 0.60 were taken after Varimax rotation was performed.

Table 1 shows descriptive statistics of all 18 locations in six transects to express spatial variation on nutrients distribution and physicochemical properties at high and low tides. Behavior of different variables in each transect was studied by considering mean value of all location in each transect due to high hydrodynamism of coastal area. Generally, pH, temperature, oxidation reduction potential, salinity and electrical conductivity values more or less followed tidal cycle with high values at high tides. Seawater buffering capacity causes a very narrow limit and responsible for the observed limited variation (Moresco et al., 2012; Riley and Chester, 1971). Dissolved oxygen (DO), turbidity, sulfate and all the nutrients (ammonia, nitrate, phosphate) values were highest at low tide. In tropical aquatic systems, oxygenation is the result of an imbalance between photosynthesis, degradation of organic matter, reaeration processes and physicochemical properties of water (Hernández-Romero et al., 2004).

Next, PCA was used to discover spatial variation of nutrients and physicochemical patterns of coastal water due to tidal effect. Measure of Sampling Adequacy (MSA) scored for PCA was 0.643 which according to Kaiser's empirical confirmation of sampling adequacy classification as mediocre. Communality scores for each parameter summarized in Tables 2 and 3 were above 0.6, indicating that parameters share variances. PCA components of high and low tides accounted of 76.08% and 75.46%, respectively. Four principal components were extracted at low and high tide. High load of salinity and electrical conductivity at high tide explained characteristics of fully ionized ions contributed by seawater which contains 90% fully ionized ions (Church, 1989). O'Boyle et al. (1999) has suggested that positively loaded nutrients with negative loadings of DO, pH and ORP in PCA outputs indicated that nutrients contribution related with pollution sources. According to Radojevic and Bashkin (2006) increased of ammonia levels are indicative of pollution which sewage is a major source of ammonia (ammonia is results of urea breakdown by urease bacteria). At typical pH values between 6 and 8 and temperature of 5–30 °C, relative part of ammonia can be detected in coastal water. PCA supported this finding with positive loadings at high and low tides. Presence of nitrate is mainly due to processes such as nitrification. Oxidation of ammonia ions to nitrate by bacteria species is under aerobic

Table 1
Descriptive statistics of measured parameters at different transects during high and low tides.

Transect	Parameter	Tide condition	
		High	Low
Transect 1	pH	8.30 ± 0.07	8.26 ± 0.02
Transect 2		8.24 ± 0.02	8.24 ± 0.01
Transect 3		8.27 ± 0.04	8.23 ± 0.05
Transect 1	Temperature (°C)	28.77 ± 0.12	28.88 ± 0.19
Transect 2		28.66 ± 0.12	28.87 ± 0.15
Transect 3		28.57 ± 0.012	28.55 ± 0.12
Transect 1	ORP (mV)	−63.25 ± 4.51	−64.18 ± 0.55
Transect 2		−64.23 ± 0.99	−65.97 ± 0.88
Transect 3		−63.17 ± 0.55	−63.23 ± 0.63
Transect 1	DO (mg/L)	5.45 ± 0.31	6.47 ± 0.28
Transect 2		5.66 ± 0.46	6.56 ± 0.12
Transect 3		5.74 ± 0.40	6.42 ± 0.31
Transect 1	EC (mS/cm)	46.29 ± 0.02	46.24 ± 1.71
Transect 2		46.96 ± 1.04	46.51 ± 1.44
Transect 3		46.99 ± 1.21	44.27 ± 1.51
Transect 1	Sa (ppt)	29.98 ± 0.01	29.92 ± 0.05
Transect 2		29.96 ± 0.05	29.67 ± 0.05
Transect 3		30.00 ± 0.04	29.73 ± 0.03
Transect 1	Turbidity (m)	1.34 ± 0.05	1.66 ± 0.43
Transect 2		1.48 ± 0.05	3.48 ± 0.09
Transect 3		1.42 ± 0.14	2.34 ± 0.48
Transect 1	Ammonia (mg/L)	0.12 ± 0.01	0.14 ± 0.07
Transect 2		0.15 ± 0.02	0.12 ± 0.05
Transect 3		0.14 ± 0.03	0.18 ± 0.04
Transect 1	Nitrate (mg/L)	±0.01	±0.01
Transect 2		0.01 ± 0.01	0.05 ± 0.02
Transect 3		±0.03	±0.00
Transect 1	Phosphate (mg/L)	0.06 ± 0.01	0.09 ± 0.03
Transect 2		0.07 ± 0.03	0.08 ± 0.05
Transect 3		0.06 ± 0.01	0.07 ± 0.02
Transect 1	Sulfate (mg/L)	2256.19 ± 105.32	2351.33 ± 179.24
Transect 2		2245.16 ± 23.24	2326.50 ± 119.05
Transect 3		2247.61 ± 118.23	2218.53 ± 114.67

ORP = oxidation reduction potential; DO = dissolved oxygen; EC = electrical conductivity; Sa = salinity

Table 2
Loadings of the water quality parameters on the principal components at high tide.

Variable	Communality	High tide			
		Principal component			
		1	2	3	4
Turbidity	0.831	**0.989**	0.012	0.110	0.160
DO	0.863	−0.098	**0.894**	0.095	−0.007
EC	0.862	−0.002	**0.945**	−0.060	0.138
Sa	0.870	−0.218	**0.825**	0.399	−0.108
Temp	0.772	−0.027	**0.866**	0.174	−0.092
Ammonia	0.763	−0.315	**0.695**	0.078	0.235
Nitrate	0.715	0.112	0.152	**0.817**	0.102
Phosphate	0.692	0.094	−0.229	**0.772**	−0.120
Sulfate	0.759	0.289	0.175	0.186	**0.755**
pH	0.869	−0.322	0.120	0.342	0.472
ORP	0.611	−0.141	−0.703	−0.045	−0.064
Eigenvalue		2.55	1.68	1.36	1.23
Variance (%)		21.26	33.20	11.34	10.28
Cumulative		21.26	54.46	65.80	76.08

condition. Since unaerobic condition was observed in this study (Table 2), higher ammonia concentration compared to nitrate concentration was found in study area. Phosphate loadings at high and low tides were also observed in coastal water of Port Dickson. Main anthropogenic sources of phosphate are discharge of raw or treated sewage, agricultural drainage as well as certain industrial waste-

Table 3
Loadings of the water quality parameters on the principal components at low tide.

Variable	Communality	Low tide			
		Principal component			
		1	2	3	4
Sulfate	0.781	**0.613**	−0.398	−0.212	−0.658
ORP	0.786	**0.884**	−0.083	−0.190	−0.091
Temp	0.837	−0.203	**0.863**	0.094	−0.092
Ammonia	0.782	−0.176	**0.862**	0.112	−0.109
Phosphate	0.667	−0.261	**0.692**	−0.320	−0.117
Turbidity	0.808	0.361	**0.645**	0.305	−0.439
Salinity	0.875	−0.051	−0.122	**0.934**	0.053
EC	0.808	−0.119	0.153	0.315	**0.829**
Nitrate	0.741	0.338	−0.043	−0.722	0.063
pH	0.727	−0.927	−0.103	−0.007	−0.094
DO	0.832	−0.512	0.434	0.349	−0.412
Eigenvalue		3.14	2.45	1.64	1.18
Variance (%)		28.54	24.30	12.93	10.69
Cumulative		28.54	52.84	65.77	76.46

water. By looking into pollution sources as a major anthropogenic impact to nutrient pollution, Port Dickson sea received pollution due to growth in tourism, shipping, small industries and urbanization along with pollution impact from marine coastal water as Strait of Malacca is one of the busiest ships route in the world (Schwartz, 2005; Thanapalasingam, 2005). Kadaruddin (1997) stated that there are 82 wastewater pipelines discharge wastewater including sewage from hotels and houses directly into the sea in northern part of Port Dickson. These discharges lead to degradation of coastal water quality causing significant negative impacts on marine ecosystem in water and sediment quality, aquatic organisms and coral reefs in particular (Chua et al., 1997; Mokhtar et al., 2009).

In this preliminary study, only coastal water samples were taken for the analysis at high and low tides and highlighted. Consequently, in the next monitoring plan of Port Dickson coastal water, a more extensive coastal area together with sediment samples will be investigated. This approach will allow us to gain information on the variability where marine sediment chemistry will help in the explanation of coastal water chemistry and pollution sources. Potential application of isotopic fingerprinting will also able to provide valuable insights into formation and spreading of nutrients in the past. The present collected data can constitute a baseline for future studies in Port Dickson.

References

APHA, 1995. Standard Methods for the Examination of Water and Wastewater 19th ed.. American Water Works Association, Water Environment Federation, Washington.

Chua, T.E., Ross, S.A., Yu, H., 1997. Malacca Straits Environmental Profile. In Aquatic Resource and Environmental Studies of the Straits of Malacca: Managing the Straits through Science and Technology. Serdang, Malaysia.

Church, A.H., 1989. The ionic of the sea. The Phytologist 68, 239–247.

Gavio, B., Palmer-Cantilloa, S., Mancera, J.E., 2010. Historical analysis (2000–2005) of the coastal water quality in San Andrés Island, SeaFlower Biosphere Reserve, Caribbean Colombia. Marine Pollution Bulletin 60, 1018–1030, http://dx.doi.org/10.1016/j.marpolbul.2010.01.025.

Hernández-Romero, A., Tovilla-Hernández, C., Malo, E.A., Bello-Mendoza, R., 2004. Water quality and presence of pesticides in a tropical coastal wetland in southern Mexico. Marine Pollution Bulletin 48, 1130–1141, http://dx.doi.org/10.1016/j.marpolbul.2004.01.003.

Kadaruddin, A., 1997. Penggunaan & pengurusan zon pinggir pantai Negeri Sembilan. Akademik 50, 3–23.

Liu, S., Lou, S., Kuang, C., Huang, W., Chen, W., Zhang, J., Zhong, G., 2011. Water quality assessment by pollution-index method in the coastal waters of Hebei Province in western Bohai Sea, China. Marine Pollution Bulletin 62, 2220–2229, http://dx.doi.org/10.1016/j.marpolbul.2011.06.021.

Mokhtar, M.B., Aris, A.Z., Munusamy, V., Praveena, S.M., 2009. Assessment level of heavy metals in Penaeus Monodon and Oreochromis Spp in selected aquaculture ponds of high densities development area. European Journal of Scientific Research 30, 348–360.

Moresco, V., Viancelli, A., Nascimento, M.A., Souza, D.S.M., Ramos, A.P.D., Garcia, L.A.T., Simões, C.M.O., Barardi, C.R.M., 2012. Microbiological and physicochemical analysis of the coastal waters of southern Brazil. Marine Pollution Bulletin 64, 40–48, http://dx.doi.org/10.1016/j.marpolbul.2011.10. 026.

O'Boyle, S., Mcdermott, G., Wilkes, R., 1999. Dissolved oxygen levels in estuarine and coastal waters around Ireland. Marine Pollution Bulletin 58, 1657–1663, http://dx.doi.org/10.1016/j.marpolbul.2009.07.002.

Praveena, S.M., Siraj, S.S., Suleiman, A.K., Aris, A.Z., 2011a. A brush up on water quality studies of Port Dickson, Malaysia. Research Journal of Environmental Sciences 5, 841–849. http://dx.doi.org/10.3923/rjes.2011.841.849.

Praveena, S.M., Kwan, O.W., Aris, A.Z., 2011b. Effect of data pre-treatment procedures on principal component analysis: a case study for mangrove surface sediment datasets. Environmental Monitoring and Assessment. http://dx.doi.org/10.1007/s10661-011-2463-2.

Radojevic, M., Bashkin, V.N., 2006. Practical Environmental Analysis. Royal Society of Chemistry, Cambridge.

Riley, J.P., Chester, R., 1971. Introduction to Marine Chemistry. Academic Press, London.

Schwartz, M.L., 2005. Encyclopedia of Coastal Science. Springer, Netherlands.

Thanapalasingam, V. 2005. Pollution status of the sungai skudai river system through heavy metals. Master Thesis. Universiti Teknologi Malaysia, Johor, Skudai.