J. Environ. Sci. & Natural Resources, 8(2): 15-19, 2015 ISSN 1999-7361

Effects of Tidal Events on the Water Quality in the Merbok Estuary, Kedah, Malaysia

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Abstract

This study was carried out to observe effects of tidal events on the water quality parameters at Merbok estuary, Kedah, Malaysia. Twenty four hours sampling were conducted at Station 1, 2 and 3 from 12th November (spring tide) to 3rd December (neap tide) 2011 on weekly interval. Results showed that water quality parameters varied with the following ranges: temperature (26.10 - 30.7°C), pH (6.29 - 7.22), dissolved oxygen (0.65 - 5.48 mgL^{-1}), salinity (0.50 – 35PSU), nitrate (0.037 - 0.647mgL^{-1}), nitrite (0.09 - 0.36 mgL^{-1}), ammonia – N (0.03 - 3.05 mgL^{-1}), phosphate (0.03 - 0.10mgL^{-1}). Kruskal Wallis H test showed that water quality parameters were significantly different among sampling stations ($p<0.01$). Mann-Whitney U test result showed that water quality parameters were significantly different between spring and neap tides ($p<0.01$) except temperature and nitrate. Parameters such as temperature, salinity, nitrate, ammonia – N and phosphate recorded higher in spring tide while, DO, pH and nitrite were higher in neap tide.

Key words: Estuary, Neap tide, Spring tide, Water quality

Introduction

Estuaries are water sources for domestic, industrial, agriculture and aquaculture. Good water quality and a healthy aquatic ecosystem are essential to maintain fish and other aquatic biota (Arimoro *et al.*, 2008). Water quality is affected by the natural processes as well as anthropogenic activities. Degradation of water quality, physical habitat and biological integrity of lotic system are often the result of these activities (Varol and Sen, 2009). Tide as natural phenomenon on affect water quality such as water temperature (Olausson and Cato, 1980), salinity (Chou *et al.*, 2011), pH (Spellman, 2011), dissolved oxygen (Nelson, 1994), nitrogen (Day *et al.*, 1989) and phosphate (Goldman and Horne, 1983). Although water quality changes in estuary is influenced by high and low tides resulting environmental changes in estuarine waters. Therefore, the present study was undertaken to investigate the effects of tidal events on the water quality in the Merbok estuary**.**

Materials and Methods

Water samples collection and analytical methods

Twenty four hours sampling were conducted at Station 1 (St 1), Station 2 (St 2) and Station 3 (St 3) of the Merbok estuary. Samples were collected at 12th November (spring tide) to 3rd December (neap tide) 2011 on weekly interval. During each sampling week, there were four sampling sessions with six hour interval. Water samples were collected by acid washed polythene bottles (1.5 liter) from each station (three replicates) for laboratory analysis and were kept in the dark and cool temperature (4°C) in the cool box before transporting to the laboratory. Then the collected samples were kept in a refrigerator at a temperature below 4°C to reduce the activities and metabolism of the organisms in the water (Adams, 1991). Temperature and salinity were measured with Hydrolab Surveyor 3 Data Logger (Model no# SVR3-DL, USA). The pH was measured by a pH meter (eco Testr TM, pH = 2). Dissolved oxygen (DO) was recorded by a DO meter (YSI Model 52). Nitrite (NO_2^-) and nitrate (NO_3^-) concentration were measured using calorimetric method and cadmium reduction method (Strickland and Parsons, 1972). Phosphate (PO_4^{3-}) was measured by the ascorbic acid method following Strickland and Parsons (1972). Ammonia low-level indophenols method (APHA, 1991) was used to determine the concentration of ammonium-N (NH_4^+) (HITACHI, Model no.U-1900, Japan).

Statistical analysis

Non-parametric statistical (Kruskal Wallis H) test was performed to observe the difference among the sampling stations. Mann-Whitney U test were performed to observe the effect of tides among water quality parameters (Ho, 2006).

Results and Discussion

Temperature

During spring tide water temperature varied from 26.10 to 30.70°C with the mean value of 28.84 ± 1.04°C while during neap tide the mean value of water temperature was 29.18 ± 0.84°C with the range of 27.70-30.50°C (Fig. 1). The highest temperature (30.70°C) was recorded at Station 2 (H T) and the lowest (26.10°C) at Station 1 (L T). Kruskal Wallis H test showed that temperature was significantly different between stations ($p<0.01$). Mann-Whitney U test result showed that temperature was not significantly different between spring and neap tide ($p>0.05$). It may be due to shallow depth at mid-stream (Station 2). Olausson and Cato (1980) stated that temperature in tropical estuaries is more stable compared to temperate estuary. Solar radiation mainly controls the temperature of estuary. In addition, estuary received heat from tidal flow from the sea. This study also showed that water temperature was higher at high tide due to inflow of sea water from downstream to upstream. Day *et al.*, (1989) reported that rivers are usually cooler than the coastal water in the estuarine system and the apparent variation of temperature in the water column is significant; due to gradual decrease of temperature from the river mouth towards upstream.

pH

pH value varied from 6.29 to7.22 with the mean value of 6.68 ± 0.21 during spring tide while during neap tide the mean value of pH was 6.76 ± 0.17 with the range of 6.46 to 7.09 (Fig. 2). The highest pH value (7.22) was recorded at Station 3(downstream) during high tide and the lowest pH (6.29) at Station 1 (upstream) during low tide. Kruskal Wallis H test showed that pH was significantly different between stations ($p<0.01$). Mann-Whitney U test result showed that pH was significantly different between spring and neap tide ($p<0.05$).

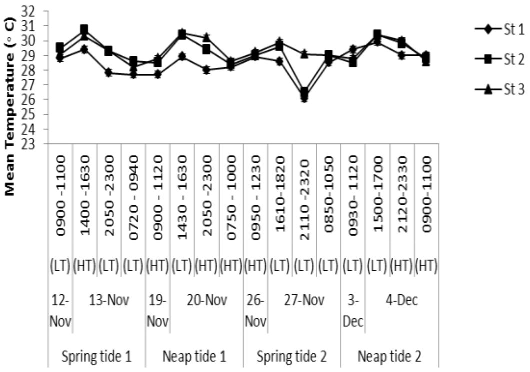

Fig. 1. Mean water temperature of Merbok River estuary at different sampling stations during 24 hour observation (n= 288)

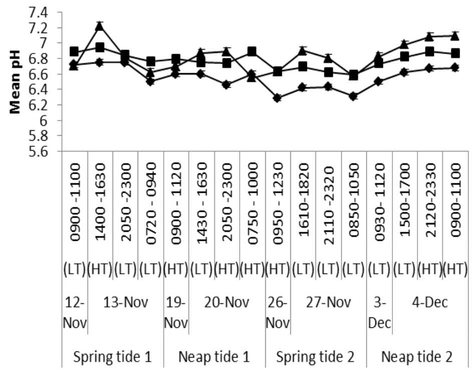

Fig. 2. The average concentration of pH of Merbok River estuary at different sampling station during 24 hour observation (n= 288)

Perkins (1974) reported that pH was lower in the upper part of the estuary may be due to decomposition occurs in the mangrove area. The author also stated that pH was higher in the downstream because sea water is slightly alkaline (7.5 to 8.4) in nature. According to Spellman (2011), pH value ranges from 6.5 to 8.5 is suitable for estuarine organisms. The present study results similar with Spellman (2011) study.

Dissolved oxygen (DO)

During spring tide dissolved oxygen (DO) values varied from 0.65 – 4.79 mgL^{-1} with the mean value of 2.33 ± 0.93 mgL^{-1} while during neap tide the mean value of DO was 3.01 ±1.41 $mgL^{-1}$with the range of 0.8-5.48 mgL^{-1}(Fig. 3). The highest DO (5.48 mgL^{-1}) was found at Station 2 (high tide) and the lowest (0.65 mg^{-1}) at Station 2 at low tide. It may be due to upward movement of tidal surges which entrap oxygen from air. It may also be influenced by generated wave action at high tide which increased rate of oxygen saturation. DO was significantly different between stations (Kruskal Wallis H test, $p<0.01$), and between spring and neap tide (Mann-Whitney U test, $p<0.01$). The present study observed lowest (0.65) DO at night and this may due to cessation of photosynthesis. Another study conducted by Kress *et al.*, (2002) reported that when oxygen required for oxidation of organic matter exceeds the oxygen produced by photosynthesis may result in ultimate lowering of dissolved oxygen level in the water body. Nelson *et al.*, (1994) inferred that neap-spring tidal cycle may be considered as one of the fundamental processes that control dissolved oxygen in an estuary.

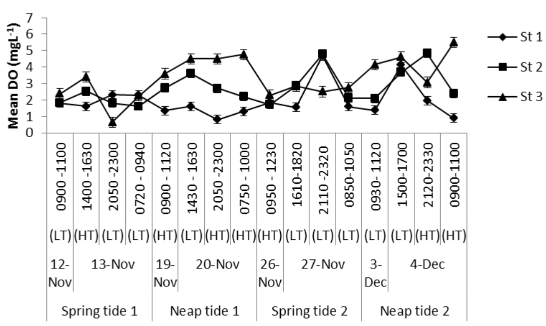

Fig. 3. Mean DO of Merbok River estuary at different sampling stations during 24 hours observation (n= 288)

Salinity

The concentration of salinity varied from 0.50 - 35.00 PSU with the mean value of 16.52 ± 9.90 PSU during spring tide while during neap tide the mean value was 11.36 ± 5.05 PSU with the range of 1.50 - 18.30 PSU (Fig. 4). The maximum salinity (35.00 PSU) was recorded at Station 2 and 3 (low tide) and the minimum (0.50 PSU) at Station 1 (low tide). Kruskal Wallis H test result showed that salinity was significantly different between stations ($p<0.01$). Mann-Whitney U test result showed that salinity was significantly different between spring and neap tide ($p<0.01$).

The present study showed that the highest salinity was recorded at Station 2 and 3 (mid and downstream) and the lowest salinity at Station 1 (upstream) during 24 hour observation. Fig. 4 shows that during all sampling sessions, upper reaches of the river (Station 1) recorded lower salinity compared with other stations. It may be due to fresh water influx from upper stream region. Previous study conducted by Hii et al. (2006) and Chou *et al.*, (2011) reported that lowest salinity was observed upper zone of the estuary. Present study also found that the highest salinity in the downstream is due to the presence of salt and halide ions in sea water and cessation of freshwater flow from upper reaches. Similar pattern result was observed by Hsu *et al.*, (1999).

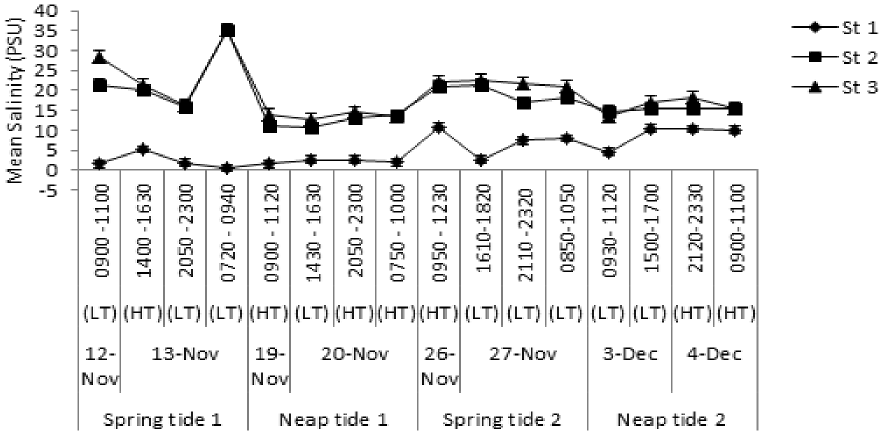

Fig. 4. Mean salinity of Merbok River estuary at different sampling stations during 24 hour observation (n= 288)

Nitrate (NO_3^-)

During spring tide the concentration of nitrate ranged from 0.037- 0.647 mgL^{-1} with the mean value of 0.22 ± 0.186 mgL^{-1} while during neap tide the mean value was 0.18 ± 0.11 mg^{-l} with the range of 0.053-0.48 mgL^{-l} (Fig. 5). The maximum nitrate was at Station 1 (0.647 mgL^{-1}) and the minimum (0.037 mgL^{-l}) at Station 3 during low tide. Nitrate was significantly different among stations (Kruskal Wallis H test, $p<0.05$), but insignificant between spring and neap tide (Mann-Whitney U test, $p>0.05$). Present study found that during spring tide nitrate value is higher compared with neap tide. This study also showed that the highest nitrate was recorded at upper reaches (Station 1) of the river system during high tide and it may be due to agricultural land run off and nitrification in the sediments and decomposition of organic matter. Previous studies by Selvam *et al.,* (1994) and Day *et al.,* (1989) observed the similar results.

Nitrite (NO_2^-)

Nitrite values varied from 0.09- 0.35 mgL^{-l} with mean 0.18 ± 0.06 mgL^{-l} during spring tide while during neap tide the mean value was 0.22 ± 0.06 mgL^{-1} with the range of 0.12 - 0.36 mgL^{-l} (Fig. 6). The maximum nitrite (0.36 mgL^{-l}) was at Station 3 (high tide) and the minimum (0.09 mgL^{-l}) at Station 1 (low tide). Kruskal Wallis H test showed that nitrite was significantly different among stations ($p<0.01$). Mann-Whitney U test showed that nitrite was significantly different between spring and neap tide ($p< 0.01$). The present study result observed that the highest nitrite concentration was recorded at lower zone (Station 3) at high tide and the lowest at upper zone (Station 1) at low tide. It may be due to surface run off from upstream area and nitrification in the sediments. Day *et al.,* (1989) observed the similar result.

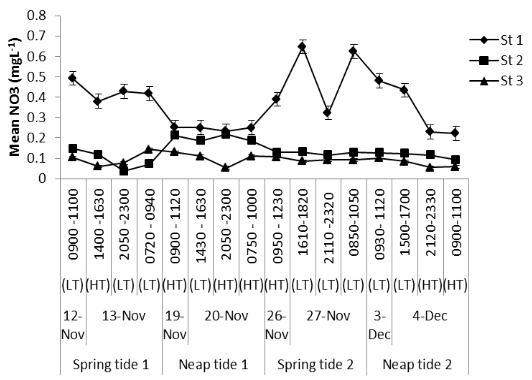

Fig. 5. Nitrate concentrations (mean ± SE) of Merbok River estuary at different sampling stations during 24 hour observation (n= 288)

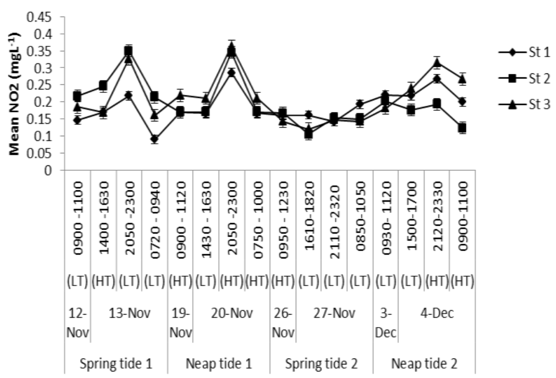

Fig. 6. Concentration of nitrite (mean ± SE) of Merbok River estuary at different sampling stations during 24 hour observation (n= 288)

Ammonium (NH_4^+)

The concentration of ammonium varied from 0.03 - 3.05 mgL^{-l} with the mean value of 0.73 ± 0.90 mgL^{-l} during spring tide while during neap tide the mean value was 0.83 ± 0.72 mgL^{-1} with the range of 0.04 - 2.73 mgL^{-l} (Figure 7). The maximum ammonium (3.05

mgL^{-1}) was recorded at Station 1 and the minimum (0.03 mgL^{-1}) at Station 3 at low tide. Ammonium was significantly different among stations (Kruskal Wallis H test, p<0.01) and between spring and neap tide (Mann-Whitney U test, p <0.01). Present research finding showed that the highest concentration of ammonia was recorded at the upper zone of the river at low tide which may be due to anthropogenic activities in the vicinity and the upstream receives major inputs of sewage and waste. Previous study conducted by Karikari *et al.*, (2006) stated that high ammonia concentration in estuary might be caused by land activities such as sewage effluent and agriculture run-off. Present study also observed that during spring tide ammonia value was higher compared with neap tide. Previous studies by Nixon *et al.*, (1984) stated that ammonium was the major dissolved inorganic nitrogen species in a Malaysian mangrove estuary.

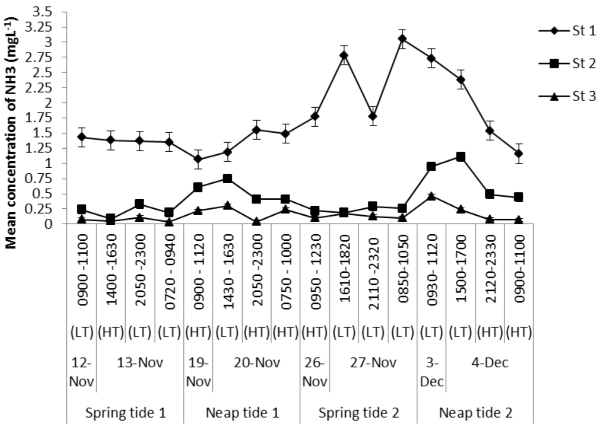

Fig. 7. Concentration of ammonium (mean ± SE) of Merbok River estuary at different sampling stations during 24 hour observation (n= 288)

Phosphate (PO_4^{3-})

During spring tide phosphate values varied from 0.1-0.036 mgL^{-1} with the mean value of 0.06 ± 0.02 mgL^{-1} while during neap tide the mean value was 0.06 ± 0.01 mgL^{-1} with the range of 0.03-0.07 mgL^{-1} (Fig. 8). The maximum phosphate (0.10 mgL^{-1}) was found at Station 2 and the minimum (0.03 mgL^{-1}) in Station 1 at low tide. Kruskal Wallis H test showed that phosphate was significantly different among stations (p< 0.01). Mann-Whitney U test showed that phosphate was significantly different between spring and neap tide (p<0.01). Agricultural, domestic and industrial wastes are major sources of soluble phosphate and frequently contribute to eutrophication (Goldman and Horne, 1983).

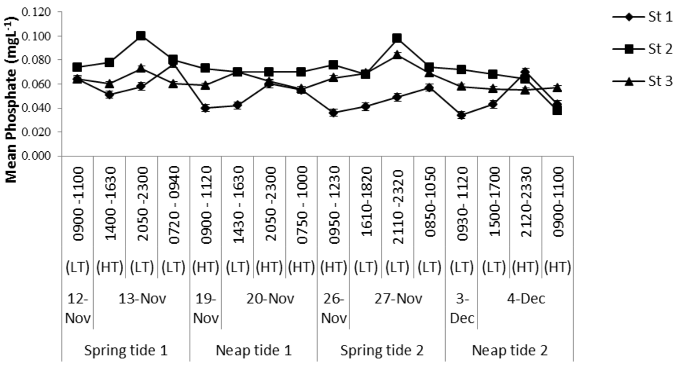

Fig. 8. The average concentration of phosphate (mean ± SE) of Merbok River estuary at different sampling station during 24 hour observation (n= 288)

The present study revealed that highest phosphate value was recorded at middle zone and the lowest at upper zone of the river system during low tide. It may be due to soil erosion, run off and discharge of sewage wastes from the adjoining villages. According to Goldman and Horne (1983) found that high inflow of total phosphate may be due to soil erosion. Day *et al.*, (1989) reported that dial variations of phosphate and nitrate are occasionally evident due to light-regulated uptake by phytoplankton, which produces low concentrations in the late morning and early afternoon and relatively high values late at night.

Conclusions

The dial variation of water quality parameters presented a clear tidal signature. Spring and neap tide revealed that the concentration of several water quality parameters in the estuarine water at upper, mid and lower zone of the river system changed according to the tide. Temperature, salinity, nitrate and ammonia recorded higher concentration during spring tide while, DO, pH and nitrite were higher during neap tide. From the above results this study revealed that water quality parameters were significantly different among sampling stations and tides.

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