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A Study of Water Quality for Sungai Kedah during High and Low Tides

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ABSTRACT

Sungai Kedah is the main river in Kedah with total length approximately 7.5 km² from Kampung Balek Hutan to Alor Setar city before discharged to the sea. The size of the Sungai Kedah basin is approximately 3605 km². The objectives of this study are to establish the pollutants profile along Sungai Kedah during high and low tides based on physical and chemical parameters. The analysis involved in-situ measurement (pH) and laboratory analysis (DO, TSS, BOD, COD and AN). During the high tide, the concentration of pollutants for pH is 7.04, TSS is 97 mg/L, BOD is 5.91 mg/L, COD is 64 mg/L and AN is 1.96 mg/L. During the low tide, the concentration of pollutants for pH is 6.92, TSS is 184 mg/L, BOD is 9.27 mg/L, COD is 89 mg/L and AN is 2.63 mg/L. Along Sungai Kedah, there are residential areas, agricultural areas, recreational park and squatters located at Alor Setar city, and Simpang Kuala wet market which are directly and indirectly affect the water quality of Sungai Kedah during high and low tides. Overall, the quality of the Sungai Kedah for the upstream is in Class II, the middle and downstream flow is in Class III.

Keywords: Water Quality, High Tide, Low Tide, WQI Index.

1. INTRODUCTION

Sungai Kedah is a main river in Kedah, Malaysia. The river passes through Alor Setar and empties into the Straits of Malacca at Kuala Kedah (Chen, 1970). The river starts at the Alor Setar suburb of Alor Mengkudu, where Sungai Alor Penyengat streams into the bigger Sungai Pendang. From there, it starts a twisting travel westbound, passing the city middle of Alor Setar where Sungai Anak Bukit streams into it. The total length of this river is about 7.5 km. Sungai Kedah is a symbol of dynamic economic resource of Kedah state. Sungai Kedah provides habitat for aquatic plant, animal and natural resource of food and protein (Ahmat, 1970). The river also contributes as attraction place for tourism and for recreational purpose.

Due to the rapid development and urbanization process around the area, nowadays, the water quality of the Sungai Kedah is significantly decreased compared to previous data. The natural state of Sungai Kedah is not at persuasive level and it can be proved by its physical appearance and smell. The decrease in water quality of Sungai Kedah is resulting from land use and human activities along the river. The land use along Sungai Kedah can be divided into four; agriculture (62%), forest coverage (28%), urban areas (6.6%) and water bodies (3%) (Mohd *et al.*, 2011). Human's activities along Sungai Kedah such as from residential, commercial, and industrial activities also contribute to the water pollution of the river.

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Water quality is highly dependent on river tides. Tides are the increase and decrease of sea levels due to the gravitational forces and the rotation of the Moon, Sun and the Earth (Wilhelm *et al.*, 1997). Nor Azman (2006) stated that the difference in water quality is due to the difference in current and flow rate between the high tide and low tide. During low tide, the volume and flow rate of the river will be less, thus, the concentration of pollutants will increase and making the river slightly more polluted. However, during high tide, the flow rate and volume of the river will be increased, thus, concentration of pollutants will be less. The current and flow during high tide is also stronger and higher during high tide compared to low tide. This will lead to proper mixing and dilution of the water therefore evenly distributing the pollutants and making it less concentrated per volume of water (Wang et. al., 1978).

The objectives of this study are; (1) to establish the pollutants profile along Sungai Kedah during high tide and low tide based on physical and chemical parameters; (2) to study the land use along Sungai Kedah and relate it to the water quality of the river.

2. MATERIAL AND METHODS

2.1 Sampling Point

Water sampling were carried out four times during the study period, involving the dry and rainy periods, the first and second was done in the month of November and December 2017 which represented the Northeast monsoon (wet period), meanwhile the third and fourth sampling was done in the month of February and March 2018 which represented the Southeast monsoon (dry period). The study sampling point was divided into five stations which is 4.6 km apart, starting at the estuary of the river which located at Kampung Balek Hutan. Sampling point was ended at the Sultanah Bahiyah Bridge which located after pass main town, Alor Setar.

Prior to in-situ parameter measurement and water sample collection, a Global Positioning System (GPS) was used to locate the exact coordinate for each sampling station. Sample of surface water was collected about 8 cm below the surface using 500 ml HDPE bottles and labelled according to sampling station. Plastic bottles containing water samples were preserved using nitric acid, were stored at 16°C in an ice box and were used for laboratory analysis. The location sampling point are listed in the Table 1 and the mapping location of sampling points is shown in Figure 1.

Table 1 Coordinate and location of sampling points

Sampling Point	Division	Coordinate Latitude (°N)	Longitude (°E)	Location
P1	Upstream	6.1104850,	100.3925470	Kampung Balek Hutan
P2	Midstream	6.1107480,	100.3901280	Kampung Lubuk Pupok
P3	Midstream	6.0996755,	100.3745786	Taman Mesra
P4	Downstream	6.1141000,	100.3654050	Kampung Pegawai
P5	Downstream	6.1167800,	100.3619160	Sultanah Bahiyah Bridge

Figure 1. Mapping location of sampling points.

2.2 Analytical Methods

The analysis of water were involved physical and chemical parameters. Physical parameters involved pH and Total Suspended Solid (TSS). While, for chemical parameters analysis involved Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Ammoniacal Nitrogen (AN). All of these experiments were conducted by using in-situ measurement and laboratory analysis as shown in Table 2.

Table 2 Parameters and method for analysis

Parameters	Methods
Biochemical Oxygen Demand (BOD)	5210 B. 5-Day BOD Test
Total Suspended Solid (TSS)	2540 D. Total Suspended Solid Dried at 103°-105°C
Chemical Oxygen Demand (COD)	5220 B. Open Reflux Method
Dissolved Oxygen (DO)	4500-O G. Membrane Electrode Method
Ammoniacal Nitrogen	4500-NH3 BC. Nessler Method
pH	4500-H^+ B. Electrometric Method

3. RESULTS AND DISCUSSION

3.1 pH

The profile of pH along Sungai Kedah during high and low tides is shown in Figure 2. According to WQI classes, during high tide, all the points are fall under Class II except for P1 (Kampung Balek Hutan) lies under Class I (7.04) which is neutral condition compared to others points is acidic. During low tide, all points are falls under Class II. The lowest range of pH is recorded at P5 (Sultanah Bahiyah Bridge) both during high and low tides, which is 6.41 during high tide and 6.13 during low tide. The highest pH obtained during high tide at P1 (Kampung Balek Hutan) is 7.04 and during low tide at P5 (Sultanah Bahiyah Bridge) is 6.13. The town center which is located near the downstream of Sungai Kedah, contributes much substance such as food waste, domestic waste and other type of solid waste which will decrease the pH of the river (Omar *et al.*, 2014). Since P4 (Kampung Pegawai) and P5 (Sultanah Bahiyah Bridge) are located at the center of the Kedah town, which is the downstream of Sungai Kedah, all the source of domestic sewage from commercial buildings, housing area and Kedah wet market are the major reason of downgrading pH. From the analysis of pH, during low tide the river water tend to be acidic since the range of pH from 6.13 to 6.92 compared to high tide, the river water tend be alkaline since the high range of pH from 6.41 to 7.04. The river is less acidic during high tide because the high volume of water somehow neutralizing effect on the water quality (Mitsch and Wise, 1998).

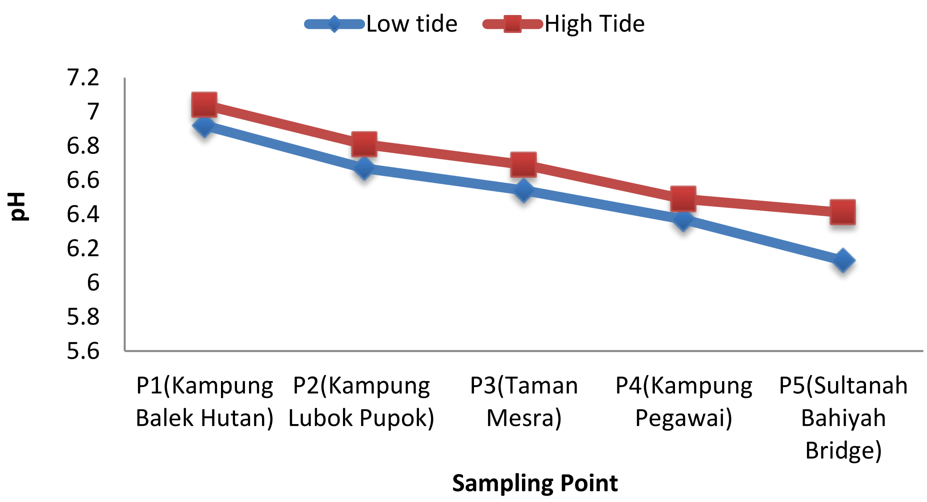

Figure 2. pH profile of Sungai Kedah during high tide and low tide.

3.2 Total Suspended Solid (TSS)

Analysis of TSS is demonstrated in Figure 3, the WQI class of TSS for P1 (Kampung Balek Hutan) during low tide within Class II as it increased to Class I during high tide. For P2 (Kampung Lubok Pupok) shown under Class III during low tide, and also rise to Class II during high tide. Meanwhile, P3 (Taman Mesra) lies in Class III during low tide also inclined to Class II during high tide. Same goes to P4 (Kampung Pegawai) and P5 (Sultanah Bahiyah Bridge) from Class IV during low tide increased to Class III during high tide. During low and high tides, P5 (Sultanah Bahiyah Bridge) showed the highest concentration of TSS with 184 mg/L during low tide and 96 mg/L during high tide, respectively. The concentration of TSS gradually increases as it flows to downstream of Sungai Kedah during both tides. The concentrations during high tide is lower compared to low tide because the water flow upstream from the sea during high tide and falls back to the sea as the tides changes (Christiansen *et al.*, 2000). Therefore, solubility and deposition of suspended solid cause sediments happens and are carried away together with the flow (Chapman *et al.*, 1996). The lowest concentration of TSS is 16 mg/L during high tide at P1 (Kampung Balek Hutan). As the volume of river getting lower during low tide, the concentration of TSS at P1 (Kampung Balek Hutan) is 23 mg/L. The construction phase by Sungai Kedah has downgrade the water quality of the river especially in surface run off and soil erosion. As major land use along Sungai Kedah covered by agriculture such as the most common one is paddy agriculture along the river, surface run off flow from agriculture area also causing erosion and increase the concentration of TSS in the river water (Puustinen *et al.*, 2005). Furthermore, routine activities especially from ships and boats traffics may effects the concentration of TSS to water column at the downstream and cause the riverbank erosion and creating a wave (Gabel *et al.*, 2017).

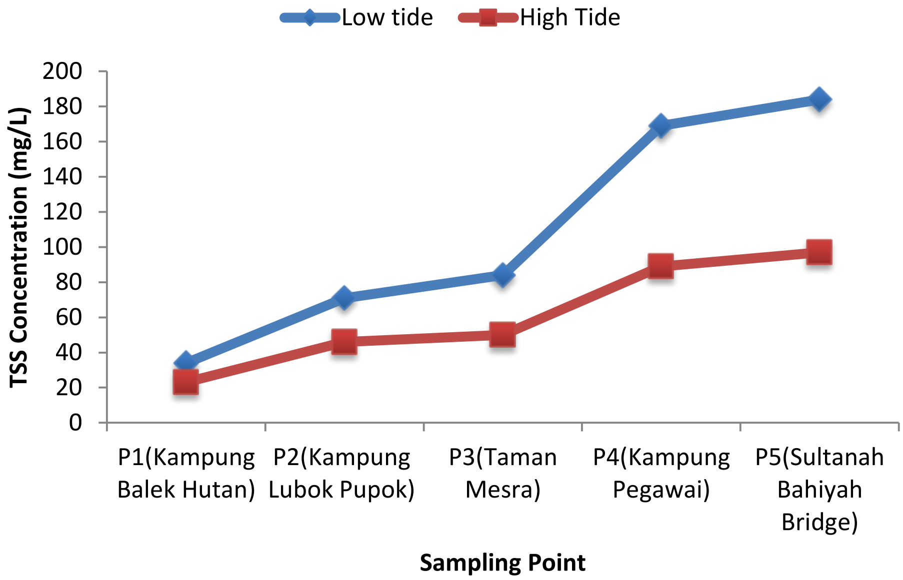

Figure 3. TSS profile of Sungai Kedah during high and low tides.

3.3 Dissolved Oxygen (DO)

Changes in DO concentration indicated a variation and temporal pattern of DO are observed within the tidal cycle for both high and low tides. DO concentration along Sungai Kedah during high tide is higher compared to low tide as shown in Figure 4. During both tidal conditions and at every changes of high and low tides, DO levels tended to decreased. Based on Figure 4, the WQI of DO during high tide for P4 (Kampung Pegawai) and P5 (Sultanah Bahiyah Bridge) lies under Class II while for the rest of sample points lies under Class I. During low tide, all points are lies within Class II except for the P4 (Kampung Pegawai) and P5 (Sultanah Bahiyah Bridge) is in Class III. The minimum concentration of DO during high and low tides lies at P5 (Sultanah Bahiyah Bridge). During high tide, all sampling points showed not too much different within range of 6.1 mg/L to 7.6 mg/L. During low tide, the lowest concentration of DO is 3.6 mg/L. The concentration of DO during low tide is slightly lower compared to high tide. Based on Figure 4, the gap between low and high tides at P5 (Sultanah Bahiyah Bridge) shown a high range by 3.6 mg/L to 6.1 mg/L respectively. A low concentration of DO showed that the water quality is low and also the presence of organic waste in the river, then the microorganisms multiply rapidly and use more oxygen without enough concentration of DO can be replaced in the river especially to downstream area (Abowei, 2010). Furthermore, storm water runoff from agricultural fields and urban areas, lawn clippings, and other materials from around residential areas also contributes into the concentration of dissolved oxygen.

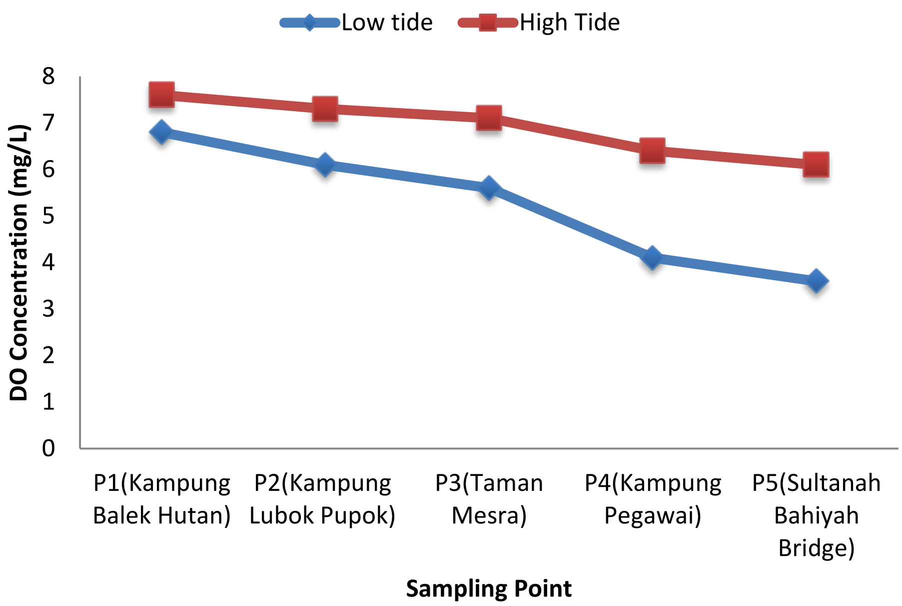

Figure 4. DO profile of Sungai Kedah during high and low tides.

3.4 Biochemical Oxygen Demand (BOD)

BOD concentration along Sungai Kedah during high tide is lower compared to low tide as shown in Figure 5. The WQI for BOD parameter for all sampling points along Sungai Kedah during high tide is shown under Class III except P1 under Class II which is located at upstream. During low tide, the WQI of BOD for P1 (Kampung Balek Hutan), P2 (Kampung Lubok Pupok) and P3 (Taman Mesra) were lies within Class III. For downstream, P4 (Kampung Pegawai) and P5 (Sultanah Bahiyah Bridge) lies under Class IV. The maximum concentration of BOD during high tide is 5.91 mg/L lies at P5 (Sultanah Bahiyah Bridge). This happen due to organic materials in sewage discharged directly into the river because there are housing areas along Sungai Kedah. During low tide, the maximum concentration of BOD is 9.27 mg/L at P4 (Kampung Pegawai).

High BOD value in the river can be attributed to untreated or partially treated sewage and discharged from agro-based and manufacturing industries (Abdullah, 1995). Land uses activities around Alor Setar City whether by commercial building as well as housing area also affected the concentration of BOD. These daily activities contribute to the present of organic trash such as organic materials and decomposing food in sewage causing oxygen shortfall in the river structure (Merrington *et al.*, 2002). The minimum BOD concentration during low tide is 3.21 mg/L and during high tide is 2.17 mg/L at P1 (Kampung Balek Hutan). The concentration of BOD during high tide is slightly lower compared to low tide. A high concentration of BOD is an indicator of bad quality water and also shown the presence of a large number of microorganisms in the water structure, which lead to a high level of deterioration especially to downstream area, while a high BOD indicates good water quality (Carr and Neary, 2008).

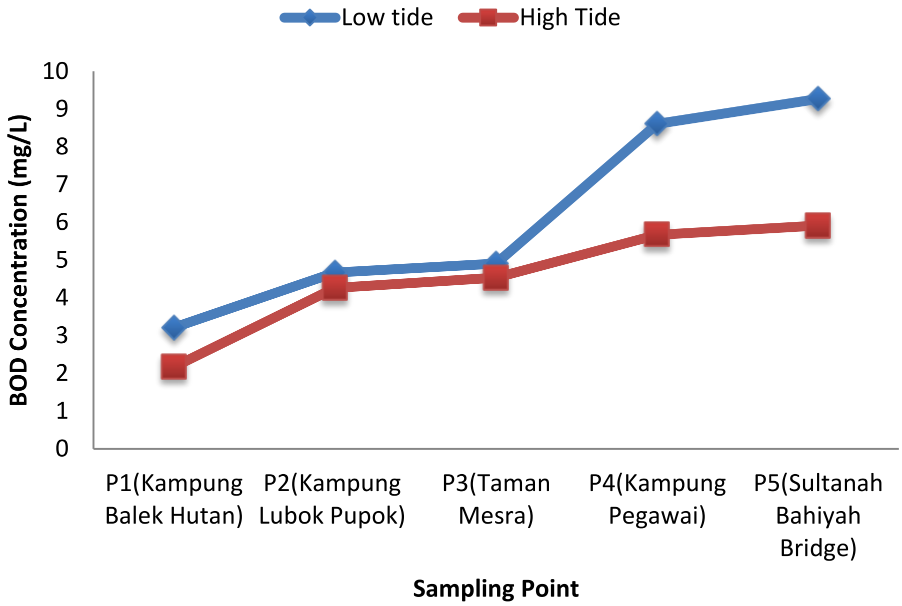

Figure 5. BOD profile of Sungai Kedah during high and low tides.

3.5 Chemical Oxygen Demand (COD)

COD also one of the important chemical parameter in determining the water quality of Sungai Kedah. BOD indicates only organic pollutant while COD indicate all parameter including organic and inorganic pollutants. As the result COD value is always higher than BOD values and may be much larger when significant amount of biologically invulnerable organic matter is present in water body (Fetter *et al.*, 2017). Refer Figure 6, the WQI of COD during high tide for P1 (Kampung Balek Hutan) lies under Class II while for the P2 (Kampung Lubok Pupok) and P3 (Taman Mesra) is shown under Class III. For the rest of point is fall under Class IV. During low tide, all points are lies within Class IV except for the P1 (Kampung Balek Hutan) is Class III.

The maximum of COD concentration during high tide is 73.3 mg/L at P4 (Kampung Pegawai) and 84 mg/L at P5 (Sultanah Bahiyah Bridge) during low tide. The minimum concentration range of COD during high and low tides were occurred at P1 (Kampung Balek Hutan) with 22.4 mg/L and 34.1 mg/L, respectively. From P3 (Kampung Ganding) to P4 (Kampung Pegawai) the concentration of COD is increasing rapidly for both tides, especially during low tide. This results occurs due to existing of commercial area as well as housing area release a non-biodegradable waste into the river. The concentration of COD was increased back after P5 (Sultanah Bahiyah Bridge) as the flow through to the downstream and directly discharged to the sea due to mixing with salt water (Dai *et al.*, 2006).

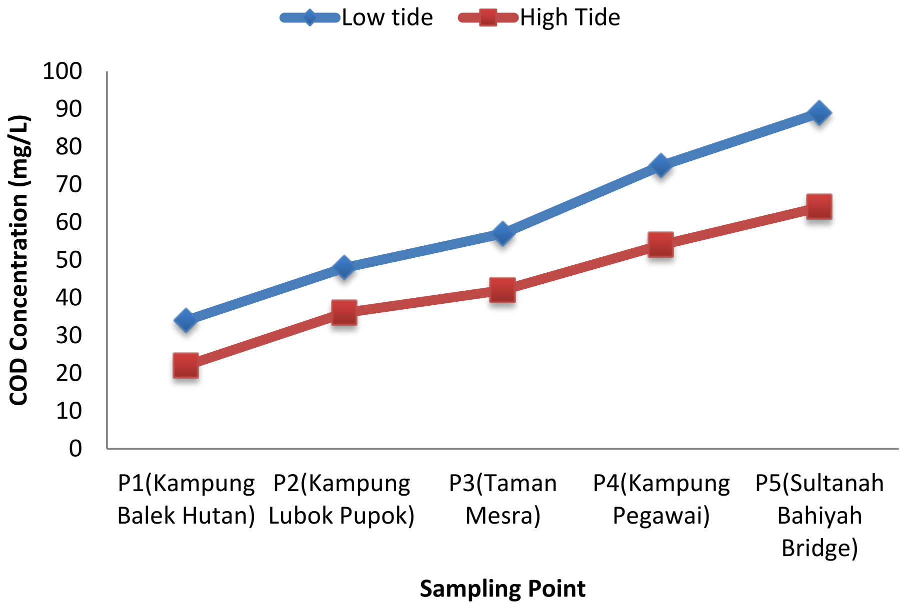

Figure 6. COD profile of Sungai Kedah during high and low tides.

3.6 Ammoniacal Nitrogen (AN)

A profile of AN is showed in Figure 7. The WQI of AN for P2 (Kampung Lubok Pupok) is fall under Class III during high and low tides. For P4 (Kampung Pegawai) and P5 (Sultanah Bahiyah Bridge) are lies under Class IV during both tides. As for P1 (Kampung Balek Hutan) and P3 (Taman Mesra) within Class IV during low tides increases to Class III during high tides. The maximum concentration of AN was showed at P5 (Sultanah Bahiyah Bridge) neither during low tide with 2.63 mg/L nor high tide with 1.96 mg/L. The minimum concentration of AN during high tide is at P1 (Kampung Balek Hutan) with 0.63 mg/L and P2 (Kampung Lubok Pupok) stated 0.87 mg/L during low tide.

At early stage of AN concentration starting from P1 (Kampung Balek Hutan) to P3 (Taman Mesra) were slowly increase as it passed upstream of Sungai Kedah to the middle-stream for both tides especially during high tide. The increasing of seaward probably because of decreasing DO concentration especially during night time, aquatic plant does not supply DO to the river water due to photosynthesis and oxygen is not consumed during day time respiration. The higher concentration of AN in Sungai Kedah comes from usage of non-environmental material especially from commercial area at P5 (Sultanah Bahiyah Bridge) included wet market, factory and household uses. As the water discharge flow through the sea, it carried the pollutants contains high amounts of AN. For P4 (Kampung Pegawai), the high concentration of AN was due to the storm water runoff which is flows into the river carrying with fertilizer, pesticide others from agriculture activities (Burton and Pitt, 2004).

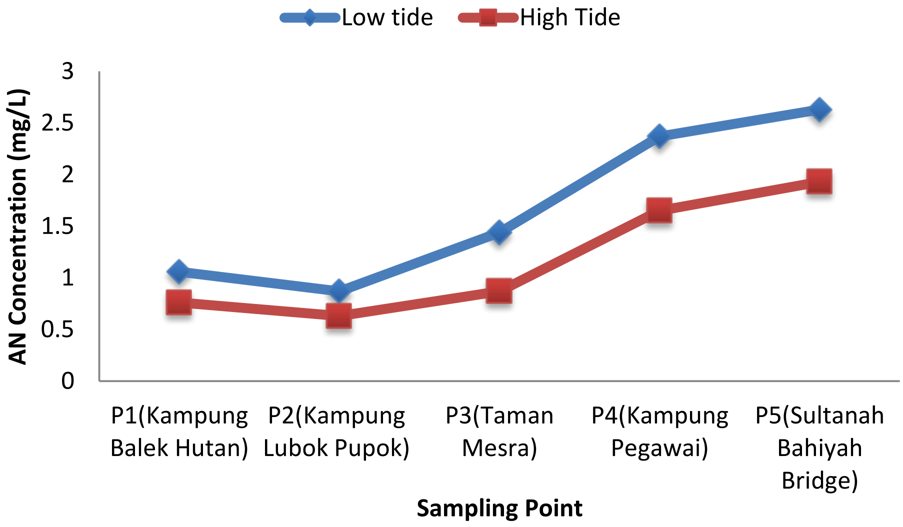

Figure 7. AN profile of Sungai Kedah during high and low tides.

4. CONCLUSION

The land use activities along Sungai Kedah and it connection to the water quality of Sungai Kedah was discussed. The higher concentration of water quality parameter during high tide are at P5 (Sultanah Bahiyah Bridge) for COD, AN, TSS and BOD, while at P1 (Kampung Balek Hutan) for AN and pH. During low tide, water quality of Sungai Kedah decreased at certain point such as P4 (Kampung Pegawai) and P5 (Sultanah Bahiyah Bridge). This is because of high concentrations of COD, AN, and BOD lead to serious microbiological defilement. Besides, sampling point, P5 (Sultanah Bahiyah Bridge) which located at downstream shown extremely polluted because of the high increases of suspended solids in the river. The main reasons for this water quality deterioration during low tide are the volume and flow rate of the river will be less. Furthermore, the land use around the sampling point at Sungai Kedah also can decreases the value of water quality. From upstream to downstream of Sungai Kedah, most of household area along the river do not have appropriate sewage disposal system and discharge directly their waste into the river. These included the squatters along Sungai Kedah and bad habit littering. Besides, around P5 (Sultanah Bahiyah Bridge) there was serious issues with high concentration of suspended solid because of diurnal boats and ships traffics may increase the concentration of suspended solid to water column especially at downstream by creating a wave and cause the riverbank erosion. Overall, the water quality of Sungai Kedah during low tide is significantly decrease compared to high tide. However, during both tides, the land use is the great influenced and contributor in increasing of the pollutant in the river water.

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REFERENCES

[1] Chen. Cholera in the Kedah River area. Medical Journal of Malaya **24**, 4 (1970) 247-56.
[2] Ahmat, S. The Structure of the Economy of Kedah, 1879—1905. Journal of the Malaysian Branch of the Royal Asiatic Society, (1970)1-24.
[3] Mohd, I., Mansor, M. A., Awaluddin, M. R. A., Nasir, M. F. M., Samsudin, M. S., Juahir, H., & Ramli, N. Pattern recognition of Kedah River water quality data implementation of principal component analysis. World Applied Science Journal **14** (2011) 66-72.
[4] Wilhelm, Zürn, & Wenzel. Tidal phenomena. Lecture Notes in Earth Sciences, Berlin Springer Verlag, (1997) 66.
[5] Nor Azman, K. Kualiti Air Sungai berdasarkan Analisis Kimia dan Kepelbagaian Alga. Universiti Teknologi Malaysia, Johor Bahru: Projek Sarjana Kejuruteraan Awam (Alam Sekitar), (2006).
[6] Wang, S.T., McMillan, A.F. and Chen, B.H. Dispersion of Pollutants in Channels with Non Uniform Velocity Distribution. The Journal of the International Association on water Pollution Research **12** (1978) 389-395.
[7] Omar, F. M., Aziz, H. A., & Stoll, S. Aggregation and disaggregation of ZnO nanoparticles: influence of pH and adsorption of Suwannee River humic acid. Science of the total environment, (2014) 195-201.
[8] Mitsch, W. J., & Wise, K. M. Water quality, fate of metals, and predictive model validation of a constructed wetland treating acid mine drainage. Water research **32**, 6 (1998) 1888-1900.
[9] Christiansen, T., Wiberg, P. L., & Milligan, T. G. Flow and sediment transport on a tidal salt marsh surface. Estuarine, Coastal and Shelf Science **50**, 3 (2000) 315-331.
[10] Puustinen, M., Koskiaho, J., & Peltonen, K. Influence of cultivation methods on suspended solids and phosphorus concentrations in surface runoff on clayey sloped fields in boreal climate. Agriculture, Ecosystems & Environment **105**, 4 (2005) 565-579.
[11] Gabel, F., Lorenz, S., & Stoll, S. Effects of ship-induced waves on aquatic ecosystems. Science of the Total Environment, (2017) 926-939.
[12] Abowei, J. F. N. Salinity, dissolved oxygen, pH and surface water temperature conditions in Nkoro River, Niger Delta, Nigeria. Adv. J. Food Sci. Technol **2**, 1 (2010) 36-40.
[13] Abdullah, A. R. Environmental pollution in Malaysia: trends and prospects. TRAC trends in analytical chemistry **14**, 5 (1995) 191-198.
[14] Merrington, G., Nfa, L. W., Parkinson, R., Redman, M., & Winder, L. Agricultural pollution: environmental problems and practical solutions. CRC Press, (2002).
[15] Carr, G. M., & Neary, J. P. Water quality for ecosystem and human health. UNEP/Earthprint, (2008).
[16] Dai, M., Guo, X., Zhai, W., Yuan, L., Wang, B., Wang, L., & Cai, W. J. Oxygen depletion in the upper reach of the Pearl River estuary during a winter drought. Marine chemistry, (2006) 159-169.
[17] Burton Jr, G. A., & Pitt, R. Stormwater effects handbook: A toolbox for watershed managers, scientists, and engineers. CRC Press, (2001).