JOURNAL OF AGROBIOTECHNOLOGY 2021, VOL 12(1S):140-149
e-ISSN: 2180-1983
http://dx.doi.org/10.37231/jab.2021.12.1S.279
https://journal.unisza.edu.my/agrobiotechnology/index.php/agrobiotechnology/index

Study on Marine Water Quality Parameters in Keluang Kecil River Estuary at Bukit Keluang, Terengganu

Nur Adiela Mohd Nasir and Nadzifah Yaakub

School of Animal, Aquatic and Environmental Sciences
Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Tembila Campus, 22200 Besut, Terengganu, Malaysia

***Corresponding author: nadzifah@unisza.edu.my**

ABSTRACT

This study presents marine water quality status of river estuarine in Keluang Kecil River Estuary at Bukit Keluang. River estuarine water is classified in Class E in MWQI. In the subsequent MWQI with 0 to 100 scales, marine water quality at 0 will be described as "Poor" and 100 as "Excellent". This study aims to determine water quality parameters and the water quality status of river estuarine by using Malaysia Marine Water Quality Index (MMWQI). In-situ and ex-situ analyses in this study were conducted for five sampling points that had been selected in the Keluang Kecil river estuary. In-situ parameters, dissolved oxygen (DO), pH, temperature, salinity and ammonia, were measured using YSI Professional Plus Series Multi-parameter during sampling. At the same time, water samples for total suspended solids, phosphate, nitrate and faecal coliform were collected and analysed in the laboratory using a standard procedure based on American Public Health Association (APHA), 2017 and HACH methods and then were compared with the Malaysia Marine Water Quality Standard (MMWQS). The average value of ammonia, nitrate, phosphate and TSS were not within the acceptable limit or standard value set by Department of Environment (DOE) except for dissolved oxygen and faecal coliform. Based on the one-way analysis of variance (ANOVA) result, there are significant differences ($P < 0.05$) in DO, pH, temperature, salinity, ammonia, TSS and FC in water between stations except for nitrate and phosphate. Marine Water Quality Index (MWQI) was measured for all the sampling stations (S1, S2, S3, S4 and S5) using a formula set by DOE (2019). The mean of MWQI for the Keluang Kecil river estuary measured was 43.45. Thus, the river estuary is classified as Poor (0 – 49). This study can maintain the marine water quality to conserve estuary biodiversity. This study was needed to prevent the possibility of water pollution and water quality can be monitored in that area in the future. The understanding of this study about water quality is to maintain the water quality and facilitate the management as actions can be taken by local authorities and other government agencies to maintain and improve the water quality and create boundaries and regulations that can bring back nature.

Keywords: water quality, river estuarine, marine water quality index, analysis of variance, water pollution

INTRODUCTION

According to Nasir et al. (2019), an estuary receives continuous mixed inflow from seawater and freshwater. This phenomenon leads to the estuary area receiving nutrients from land-based points and non-point sources, contributing to varying nutrients (Nasir et al., 2019). Nutrients such as nitrate, ammonia and phosphate are being used as a benchmark for indicating the water quality of estuaries and whether the water bodies can maintain their designated uses or not (Nasir et al., 2019). Estuaries are an essential component of complex and dynamic coastal watersheds. Seas occupy large areas of the earth's surface, and protect against contamination is vital for humans. The vast marine regions in Malaysia consist of estuaries, islands, coastal and seaside areas that are vulnerable to pollutants due to urbanisation and tourism. The majority of Malaysians are located a few kilometres from the coast (Law & Othman, 1990). Seawater contamination is a major environmental issue since human activity at the coastal area and marine water lead to diverse types of pollutants discharged into seawater (Bazzi, 2014). Due to human activity in this area, it is crucial to determine the contamination levels in this water body and aquatic species in the long term effects (Yunus et al., 2015).

The polluted seawater affects the ecological system (Puthiya Sekar et al., 2009). The rapid development and population growth in Malaysia have caused water contamination. Marine water is an interacting component with the land system, where waste from the land will enter directly into the sea. Rapid development has created a lot of human waste, including residential wastes, domestic wastes and transportation wastes that will go into the water bodies (Huang et al., 2015). Water quality should also be maintained to ensure that no pollutants will exceed the standards that can affect human health that having water sport and other activities at the coastal area. However, limited study has been carried out on the water quality in this area of study. The major pollutants in the country's marine waters are suspended solids, Escherichia coli, oil and grease (Huang et al., 2015). Pantai Bukit Keluang is an ideal destination for some water sports such as swimming, snorkelling and windsurfing. This beach is one of the famous destinations for tourism because it has beautiful scenery and recreational value. This study is conducted to reduce water pollution and protect seawater for public use since the status of water quality in those three areas will be revealed in this study (Law & Othman, 1990). Human activities in the estuary and coastal region have been recognised to be the significant contributor to the pollution of seawater (Ngah et al., 2012).

Based on DOE, 2019, the higher TSS value is shown by most data obtained, especially from river estuarine regions. The high TSS parameter level was identified related to the land use development activities (Environmental Quality Report, DOE, 2019). Anthropogenic activities such as land use development in the estuarine river area and untreated domestic waste effluent contribute to unlawful discharge of waste, leading to the declining quality of the water (Ngah et al., 2012). The degradation of estuary's water quality and eventually the coastal areas in the South China Sea will happen due to various anthropogenic activities, including industrial discharges, agricultural run-off and irrigation, and municipal water pollution from homes and businesses (Nasir et al., 2019). Besides, the number of excellent marine water quality in the estuary area had decreased (Huang et al., 2015). As this area received many visitors throughout the year due to its attractive activities and restaurant facilities, estuary water quality is likely to be affected.

Monitoring water quality has become a severe matter and essential to better protect human health and the environment (Hanafiah et al., 2018). Water quality determination is needed to monitor water pollution (Hefmi et al., 2019). Early detection of changes in water quality parameters will lead to the successful management of estuary and coastal ecosystems (Fabricius & De, 2004). This study can improve the management of such activities that contribute to the water pollution at this river estuarine area. Furthermore, by determining the cause and effect of Bukit Keluang river estuarine water destruction, actions can be taken by local authorities and other government agencies to maintain and improve the water quality and also to create boundaries and regulations (Hanafiah et al., 2018). The water quality at Bukit Keluang estuary needs to be studied comprehensively because of the area's importance as a recreation centre for humans. Furthermore, the lack of previous research studies that had been done on water quality at Bukit Keluang river estuary has allowed for further analysis.

MATERIALS AND METHODS

Study Area

This study was conducted at Bukit Keluang estuary in Besut, Terengganu. The estuary is located where Keluang Kecil River meets the South China Sea. Five sampling points have been selected along Keluang Kecil River. Water sampling was conducted two times (morning and evening) for two days, on 10 May 2021 and 11 May 2021. Sampling locations were started where the value of water salinity nearly reached ten and ended where the value of water salinity surpasses almost 25. Global Positioning System (GPS) was used to locate the coordinates for each sampling location. The length of the estuary is about 2.5 km and was divided into five points which were 500 metres apart.

Figure 1: Sampling Location

Table 1 Coordinates of sampling locations

Sampling Station	Latitude	Longitude
S1	5°47'2.05"N	102°35'47.26"E
S2	5°47'19.83"N	102°35'59.99"E
S3	5°47'29.35"N	102°36'15.52"E
S4	5°47'32.76"N	102°36'34.60"E
S5	5°47'28.89"N	102°36'48.04"E

In-situ

Based on Samsudin et al. 2019, surface water quality was measured for in-situ parameters at each station for dissolved oxygen, salinity, ammonia, pH and temperature at one meter below the water surface by using the parameter probe YSI Professional Plus Series Multi-parameter. Calibration must be done to prepare for making measurements (Suratman et al., 2014). The sensors were rinsed with distilled water. The data displayed were recorded. Three replicates were done to get the data accurately (Al-badaii et al., 2013). After the YSI Professional Plus Series Multi-parameter being used, it was rinsed with distilled water and was dried with tissue paper.

Ex-situ

The water samples were collected into 1 L high-density polyethylene (HDPE) bottles that are pre-cleaned with acid-washed by soaking overnight in 5% concentrated nitric acid before rinsing thoroughly with distilled water to remove all traces of contaminants and avoid potential cross-contamination (APHA, 2017). Surface marine water samples were collected from five different sampling locations using HDPE bottles with triplicate (Al-badaii et al., 2013; Gandaseca et al., 2011). The surface water samples were collected at 30 cm depth (Samsudin et al., 2019). When the targeted depth is reached, let the water flow into acid-washed 1 L HDPE bottles until complete, without any air bubbles (Hanafiah et al., 2018). After collecting water samples, HDPE bottles were labelled accordingly to the sampling stations and date. All models were preserved with nitric acid and were immediately stored in a cooler box for further laboratory analysis at approximately 4°C to minimise microbial activity in the water (APHA, 2017). The samples should be reached in the laboratory within 24 hours of sampling time (Rak et al., 2011). The parameters that were analysed in the laboratory are faecal coliform, phosphate, nitrate and TSS. Sample bottles were preserved and protected from recontamination, and the actual composition of water samples must be maintained (Hanafiah et al., 2018). The collected samples were analysed as per the standard method. Standard procedures based on APHA (2017) were followed for water samples collection and water samples analysis.

Data Analysis

The mean of *in-situ* and *ex-situ* parameters was compared to the Malaysia Marine Water Quality Standard by the Department of Environment, Malaysia. MWQI was calculated for each sampling location. Six water quality parameters were selected in this study; DO, ammonia, nitrate, phosphate, TSS, and faecal coliform refer to the Marine Water Quality Index (MWQI) (DOE, 2019) as a guideline. When the MWQI was calculated, it was referred to its respective classification; excellent, good, moderate and poor. MMWQI was calculated as follows:

$$\text{MMWQI} = q_{I\text{do}}^{0.18} \times q_{I\text{fc}}^{0.19} \times q_{I\text{nh3}}^{0.15} \times q_{I\text{no3}}^{0.16} \times q_{I\text{po4}}^{0.17} \times q_{I\text{tss}}^{0.15}$$

Statistics Analysis

The statistical significance between all parameters was evaluated using one-way Analysis of Variance (ANOVA) (Idrus et al., 2017). The software that was used is Statistical Package for the Social Sciences (SPSS).

RESULTS AND DISCUSSION

Based on table 2, the water quality parameters at low tide and high tide were recorded. Meanwhile table 3 showed water quality parameters during rainy and sunny day were recorded respectively. From these results, a the water quality were different according to tide and seasons.

Table 2 Water quality parameters at low tide and high tides

Water quality parameters	Low tide					High tide				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
DO (mg/L)	3.70	3.75	3.87	7.89	6.91	3.98	3.61	4.05	7.58	7.62
pH	6.91	6.77	7.26	6.77	8.01	7.58	7.95	7.32	8.07	8.16
Temperature (°C)	28.85	28.93	29.89	30.83	31.00	29.60	29.57	30.87	29.83	31.71
Salinity (ppt)	11.97	13.83	15.46	17.33	20.02	15.22	20.78	16.24	23.32	23.96
Ammonia (mg/L)	0.05	0.07	0.10	0.23	0.38	0.09	0.31	0.28	0.35	0.70
Nitrate (mg/L)	2.53	2.20	2.37	2.57	2.33	1.20	1.23	1.33	1.47	1.17
Phosphate (mg/L)	2.40	1.27	1.23	1.70	1.23	1.30	1.27	1.43	1.50	1.13
TSS (mg/L)	66.67	57.67	65.00	81.33	29.00	78.33	68.00	71.67	45.33	20.00
FC (cfu/100ml)	110.00	75.33	33.00	0.00	0.00	105.33	75.00	29.33	0.00	0.00

Table 3 Water quality parameters during rainy day and sunny day

Water quality parameters	Rainy day					Sunny day				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
DO (mg/L)	5.35	5.21	6.34	7.62	7.81	5.16	5.94	6.33	7.32	7.24
pH	7.94	7.56	7.73	8.30	8.17	7.58	7.36	8.08	8.25	8.20
Temperature (°C)	29.96	29.88	29.94	30.75	29.96	29.80	29.88	31.71	30.85	31.90
Salinity (ppt)	11.28	13.32	12.00	21.41	23.06	12.78	12.08	18.63	20.55	23.00
Ammonia (mg/L)	0.07	0.02	0.08	0.03	0.47	0.16	0.22	0.26	0.32	0.42
Nitrate (mg/L)	1.00	0.90	1.50	0.90	0.53	1.33	1.40	1.13	1.30	1.20
Phosphate (mg/L)	1.37	1.37	1.43	1.37	1.10	1.47	1.43	1.37	1.37	1.10
TSS (mg/L)	59.67	45.67	54.00	50.33	27.00	68.33	48.33	60.67	54.33	37.67
FC (cfu/100ml)	87.00	56.33	19.00	0.00	0.00	98.00	65.67	27.33	0.00	0.00

Dissolved Oxygen

On the first day (10 May 2021), the DO average concentration during low tide was low at 4.99 mg/L, while during high tide, the DO concentration was high with 5.37 mg/L. High tides tend to have high DO concentrations (Pearce & Schumann, 2003). On the second day (11 May 2021), there was rainfall in the morning, and the DO concentration recorded was 6.47 m/L which was higher than in the evening, 6.40 mg/L. The DO concentration in the morning is high because of increased water levels due to rainfall (Pearce & Schumann 2003). In addition, the rain in the morning caused the water temperature to decrease. According to Bello et al. (2017) study, water temperature decline could raise the dissolved oxygen concentrations in the water.

pH

The pH value represents the alkalinity and acidity of the water body. On 10 May, there was low tide in the morning, and the pH average was 7.37, which is lower than in the evening with high tide, 7.81. Similar results from this study with the Spellman study (2011). At low tide, pH levels become low, while at high tide, pH levels become elevated. On 11 May, there was high tide in both morning and evening. The pH levels average for

morning and evening were 7.94 and 7.89, respectively. The average pH level in the morning was lower than evening due to the rainfall. The flow of rain with estuary water reduced the acidity in the water.

Temperature

On 10 May, there was low tide in the morning and the temperature average was 29.90°C, which is lower than in the evening with high tide, 30.32°C. The inflow of seawater from downstream to upstream increased the temperature of the estuary water at high tide (Day *et al*., 2015). On 11 May in the morning, there was rainfall, and the temperature average recorded was 30.10°C, which is lower than in the evening, 30.83°C. Rainfall was found to have a strong association with changes in water temperature in this estuary environment. Rainfall might result in a high discharge in the estuary. The weather was reduced during the high discharge time.

Salinity

On 10 May, there was low tide in the morning, and salinity concentration was 15.72 ppt which was lower than in the evening, 19.90 ppt due to high tide. When the tide rises, the seawater flows into a river mouth and brings greater salt levels. On 11 May 2021, in the morning, there was rainfall, and the average concentration of salinity level was 16.21 ppt, which is lower than in the evening with 17.41 ppt. This is because there was no rainfall in the evening. In the estuary, salinity levels are usually low when the freshwater flow from streams and groundwater increases by rains.

Ammonia

The combination of freshwater and seawater in the estuary causes turbulence of the water, which tends to release the ammonia from the re-suspension of the lower sediment to the surface water, especially when the tide is high (Bubu-Davies & Ugwumba, 2021). The ammonia concentration average in the morning and evening were 0.17 mg/L and 0.35 mg/L, respectively. This is because there was low tide in the morning, while there was high tide in the evening. It was also observed that the ammonia in the surface waters was more elevated during high tide. On 11 May, there was high tide in both morning and evening. The ammonia concentration average for morning and evening were 0.14 mg/L and 0.28 mg/L, respectively. The ammonia concentration in the morning was lower than evening due to the rainfall. The flow of rain with estuary water reduced river nutrient concentrations.

Nitrate and Phosphate

On 10 May, there was low tide in the morning, and the nitrate and phosphate average concentration was 2.40 mg/L and 1.57 mg/L, respectively, which was higher than in the evening with high tide, 1.28 mg/L and 1.33 mg/L, respectively. The higher concentration of phosphate and nitrate at low tide is because of the deposition of nitrate and phosphate themselves and the high decomposition of organic matter. On 11 May, there was rainfall in the morning. The nitrate and phosphate average concentrations recorded were 2.40 mg/L and 1.57 mg/L, respectively, while in the evening, with no rain, nitrate and phosphate were 1.28 mg/L and 1.33 mg/L, respectively. The rainfall causes the increase in water level and indirectly causes declining in nitrate and phosphate concentration.

Total Suspended Solid

On 10 May, a high accumulation of sediments occurred, notably during low tide on a sunny day with 59.93 mg/L of TSS concentration, while during high tide on a sunny day, there was a low concentration of TSS with 56.67 mg/L. There was a higher TSS level during low tide because of the re-suspension of the bottom sediment (Park, 2007). On 11 May, there was rainfall in the morning and the TSS average concentration recorded was 47.33 mg/L, while in the evening with no rain, TSS average concentration was 53.87 mg/L. The rainfall causes the increase in water level and indirectly causes declining in TSS concentration (Kamarudin et al., 2017).

Faecal Coliform

On 10 May, there was low tide in the morning, and the average concentration of faecal coliform was 43.67 cfu/100ml, which is higher than in the evening with high tide, 41.93 cfu/100ml. The transition from low to high tide reduced the concentration of faecal coliform in waters. Therefore, the variation of faecal bacteria concentrations at the sampling stations was shown to be strongly affected by the tide (Gao et al., 2015). On 11 May, there was rainfall in the morning. The average faecal coliform concentration recorded was 32.47 cfu/100ml (lowest), while in the evening, with no rain, the average faecal coliform concentration was 38.20 cfu/100ml (highest). The increase in freshwater discharge into the estuary system caused a declining concentration of faecal coliform. The rise in sea level would decrease the distribution of faecal coliforms, as both water and water volume have increased (Liu & Chan, 2015).

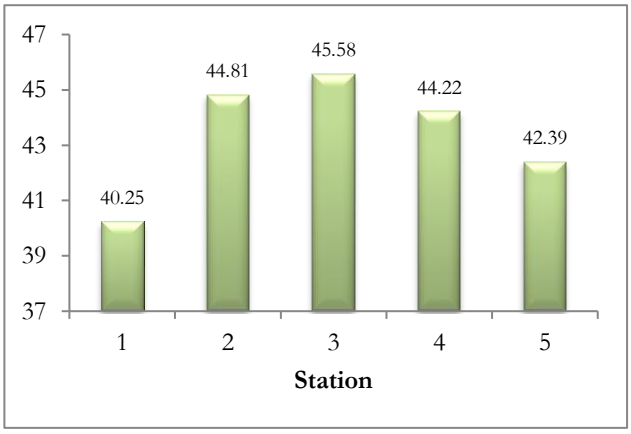

Fig. 1 Mean of MWQI between stations

Fig. 1 showed the Marine Water Quality Index (MWQI) that was measured for all the sampling stations (S1, S2, S3, S4 and S5) using the given formula set by DOE (2019). The mean of MWQI for the Keluang Kecil River estuary measured was 43.45. Thus, the estuary is classified as Poor (0 – 49) based on Marine Water Quality Index Classification DOE (2019). This is because the average value of ammonia, nitrate, phosphate, and TSS was not within acceptable limit or standard value set by the Department of Environment, Malaysian Marine Water Quality Standards and Index (2019) except for dissolved oxygen faecal coliform. The MWQI in station S1 was the lowest because the results showed that significantly higher nitrate, phosphate, TSS, and faecal coliform concentrations were detected in the upper part of the estuary. The lowest DO concentration detected in S1 was also why the MWQI in station S1 is the lowest. The aquaculture activities that operated almost along the river estuary, especially in S1, nitrate and phosphate were introduced into the water column through fish feed waste, excretion and respiration products (Suliman, 2018). The enormous effect of aquaculture activities is the enrichment of organic matter and nutrients, which reduces the dissolved oxygen and estuary water quality degradation (Suliman, 2018). The highest faecal coliform concentration in S1 was derived from discharges of untreated sewage, run-off, land used for livestock farming and recreational use. . Based on the one-way analysis of variance (ANOVA) result, there are significant differences ($P < 0.05$) in DO, pH, temperature, salinity, ammonia, TSS and FC in water between stations except for nitrate and phosphate.

CONCLUSION

To identify the quality of marine water in that area, the determination of water quality parameters for in-situ were conducted by measuring during sampling while ex-situ by water samples collection and being analysed using a standard procedure based on APHA (2017) and HACH methods in the laboratory and then were compared with the Malaysia Marine Water Quality Standard (MMWQS). As a result, the average value of

ammonia, nitrate, phosphate and TSS were not within the acceptable limit or standard value set by the Department of Environment, "Malaysian Marine Water Quality Standards and Index," (2019), except for dissolved oxygen and faecal coliform. Marine Water Quality Index (MWQI) was measured for all the sampling stations (S1, S2, S3, S4 and S5) using a formula set by DOE (2019). The mean of MWQI for the Keluang Kecil River estuary measured was 43.45. Thus, the river estuary is classified as Poor (0 – 49) based on Marine Water Quality Index Classification (DOE, "Malaysian Marine Water Quality Standards and Index," 2019). This study was highly needed to prevent the possible effects of water pollution, and water quality can be monitored in that area in future. To ensure that the anthropogenic pressures do not result in the deterioration of water quality and the ecosystem being impacted beyond sustainable levels, continuous monitoring of the water quality in this area is recommended because the lack of previous research studies on the topic has further allowed for further research analysis.

ACKNOWLEDGMENTS

The authors would like to thank Universiti Sultan Zainal Abidin for allowing the research team to carry out this research.

REFERENCES

Al-badaii, F., Shuhaimi-othman, M., & Gasim, M. B. (2013). Water Quality Assessment of the Semenyih River. Journal of Chemistry, 3216, 112–122.

APHA. (2017). Standard Methods for the Examination of Water and Wastewater. In R. B. Baird, A. D. Eaton, & E. W. Rice (Eds.), American Public Health Association (23rd ed.).

Aweng, E. R., Ismid, M. S., & Maketab, M. (2011). The effect of land uses on physicochemical water quality at Three Rivers in Sungai Endau watershed, Kluang, Johor, Malaysia. Australian Journal of Basic and Applied Sciences, 5(7), 923-932.

Bello, A. A. D., Hashim, N. B., & Haniffah, M. R. M. (2017). Predicting Impact of Climate Change on Water Temperature and Dissolved Oxygen in Tropical Rivers. Climate, 5(3). https://doi.org/10.3390/cli5030058

Bubu-Davies, O. A., & Ugwumba, O. A. (2021). Tidal Influence on Nutrients Status and Phytoplankton Population of Okpoka Creek, Upper Bonny Estuary, Nigeria. Recent Research Advances in Biology Vol. 5, 2013, 95–121.

Bui, T. D., Luong-Van, J., & Austin, C. M. (2012). Impact of Shrimp Farm Effluent on Water Quality in Coastal Areas of The World Heritage-listed Ha Long Bay. American Journal of Environmental Sciences, 8(2), 104–116. https://doi.org/10.3844/ajessp.2012.104.116

Day, J. W., Yáñez-Arancibia, A., & Hall, C. A. S. (2015). Estuarine Ecology. December 2015, 1–44. https://doi.org/10.2307/1351438

DOE, "Malaysian Marine Water Quality Standards and Index." (2019). Department of Environment. https://www.doe.gov.my/portalv1/wp-content/uploads/2019/04/BOOKLET-BI.pdf

Environmental Quality Report. DOE. (2019). https://enviro2.doe.gov.my/ekmc/digital-content/laporan-kualiti-alam-sekeliling-2019/

Gao, G., Falconer, R. A., & Lin, B. (2015). Modelling The Fate and Transport of Faecal Bacteria in Estuarine and Coastal Waters. Marine Pollution Bulletin, 100(1), 162–168. https://doi.org/10.1016/j.marpolbul.2015.09.011

Hanafiah, M. M., Yussof, M. K. M., Hasan, M., Abdulhasan, M. J., & Toriman, M. E. (2018). Water quality assessment of Tekala River, Selangor, Malaysia. Applied Ecology and Environmental Research, 16(4), 5157–5174. https://doi.org/10.15666/aeer/1604_51575174

Hefmi, R., Tanjung, R., & Hamuna, B. (2019). Assessment of Water Quality and Pollution Index in Coastal Waters of Mimika , Indonesia. Journal of Ecological Engineering, 20(2), 87–94.

Huang, Y. F., Ang, S. Y., Lee, K. M., & Lee, T. S. (2015). Quality of Water Resources in Malaysia. In Intech (Vol. 32). https://www.intechopen.com/books/advanced-biometric-technologies/liveness-detection-in-biometrics

Idrus, F. A., Chong, M. D., Abd Rahim, N. S., Mohd Basri, M., & Musel, J. (2017). Physicochemical Parameters of Surface Seawater in Malaysia Exclusive Economic Zones Off the Coast of Sarawak. Borneo Journal of Resource Science and Technology, 7(1), 1–10. https://doi.org/10.33736/bjrst.388.2017

Kamarudin, M. K. A., Toriman, M. E., Wahab, N. A., Rosli, H., Ata, F. M., & Faudzi, M. N. M. (2017). Sedimentation Study on Upstream Rreach of Selected Rivers in Pahang River Basin, Malaysia. International Journal on Advanced Science, Engineering and Information Technology, 7(1), 35–41. https://doi.org/10.18517/ijaseit.7.1.971

Law, A. T., & Othman, A. (1990). Sewage pollution in the coastal waters off Port Dickson, Straits of Malacca. Pertanika, 13(3), 375–380.

Md Yunus, S., Hamzah, Z., Wood, A. K., & Ahmad. (2015, April). Assessment of heavy metals in seawater and fish tissues at Pulau Indah, Selangor, Malaysia. In AIP Conference Proceedings (Vol. 1659, No. 1, p. 050007). AIP Publishing LLC.Yunus, S. M., Hamzah, Z., Wood, A. K., & Ahmad. (2015). Assessment of Heavy Metals in Seawater and Fish Tissues at Pulau Indah, Selangor, Malaysia. 050007(April 2015). https://doi.org/10.1063/1.4916877

Nasir, F. A. M., Suratman, S., & Le, D. Q. (2019). Distribution and Behavior of Nutrients in Besut River Estuary, Terengganu, Malaysia. Malaysian Journal of Analytical Sciences, 23(6), 1077–1089. https://doi.org/10.17576/mjas-2019-2306-15

Ngah, M. S. Y. C., Hashim, M., Nayan, N., Said, Z. M., & Ibrahim, M. H. (2012). Marine pollution trend analysis of tourism beach in peninsular Malaysia. World Applied Sciences Journal, 17(10), 1238–1245.

Samsudin, M. S., Azid, A., Khalit, S. I., Sani, M. S. A., & Lananan, F. (2019). Comparison of Prediction Model Using Spatial Discriminant Analysis for Marine Water Quality Index in Mangrove Estuarine Zones. 141(1), 472–481.

Samsudin, M. S., Azid, A., Khalit, S. I., Sani, M. S. A., & Lananan, F. (2019). Comparison of prediction model using spatial discriminant analysis for marine water quality index in mangrove estuarine zones. Marine pollution bulletin, 141, 472-481.

Suliman, S. N. S. (2018). Assessment OF Water Quality Status Of Penang Coastal Water. 4.

Suliman, S. N. S. (2018). Assessment Of Water Quality Status Of Penang Coastal Water (Doctoral dissertation, Universiti Sains Malaysia).Rak, A. E., Said, M. I. M., & Maketab, M. (2011). The Effect of Land Uses on Physicochemical Water Quality at Three Rivers at Three Rivers in Endau, Johor. August 2016.

Suratman, S., Hussein, A. N. A. R., Latif, M. T., & Weston, K. (2014). Reassessment of physico-chemical water quality in Setiu Wetland, Malaysia. Sains Malaysiana, 43(8), 1127–1131.

Wannahari, R., Abdullah, N. A., Nordin, M. F. M., & Muhammad, M. (2014). Evaluation of Heavy Metal in Coastal Water at Kelantan. American Journal of Environmental Sciences, 9(6), 505–510. https://doi.org/10.3844/ajessp.2013.505.510

How to cite this paper:
Nasir, M.A.N & Yaakub, N. (2021). Study on Marine Water Quality Parameters in Keluang Kecil River Estuary at Bukit Keluang, Terengganu. *Journal of Agrobiotechnology*, *12*(1S), 140-149