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POTENTIAL OF SEA LEVEL RISE IMPACT ON SOUTH CHINA SEA: A PRELIMINARY STUDY IN TERENGGANU, MALAYSIA

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ABSTRACT

The effect of the sea level rise was involved the existence of sea water intrusion and coastal erosion phenomenon in the coastal of Terengganu. This study aim to determine fluctuation of high and low tides of the South China Sea in their relation to water quality value of Marang and Paka Rivers as well as from wells monitoring along the Terengganu Coast. Sampling was carried out twice during high and low tides, first in November 2012 and was repeated in November 2015. For the river quality study, it involves six parameters and involves nine parameters for well survey. Two-way t-test was used under statistical analysis to differentiate between two samplings. The result of the study can be assured that sea level rise resulting in decreased concentration of salinity, EC and TDS from upstream to downstream as a result of qualitatively rise of sea level at Terengganu beach as an impact of global warming events.

Keywords: Marang and Paka Rivers; water quality parameter; well water quality; sea level rise; South China Sea.

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1. INTRODUCTION

Malaysia has received abundance amount of rainfall every year. Peninsular Malaysia has received average rainfall approximately 2400mm per year [1]. Some of the water will seep into the ground to become groundwater resources, some will undergo evapotranspiration and the rest will form surface runoff [2-3]. Some of activities related to the river are fisheries, aquaculture, sand mining, water sport activities, farming and many more activities. Years ago, rivers in Malaysia is commonly very clean and less polluted if it is compared to the present condition, this situation is resulted from the increasing of populations living along the riverbank and numerous activities carried out close to the river areas [4-5].

Some of anthropogenic activities such as settlement, sand quarries, fish farming and the natural phenomenon such as sea level rise and tidal activities are degraded the river water quality [6]. Melting glaciers and thermal expansion of seawater are among the major factors that caused sea level rise [7]. In conjunction to these phenomena, the influx of saltwater into the river through estuary was amplified. As a consequence, there is variation of water quality concentration of surface water. Besides, diurnal variation of sea level which is also known as tidal activities was also affected by this phenomenon. It was shown by the alteration of low and high tides level. Sea level rise interrupts the freshwater characteristics as the projection of salinization towards groundwater and estuaries reservoirs. Thus, disturbance in water quality of freshwater such as rivers by influx of marine water might cause a certain fish in stress condition as some species, especially at juvenile and egg stages which cannot tolerate due to change in quality of water. For example, eggs of trout cod have limited survival rate of 50% when expose to increasing of salinity level of fresh water around 450 mg/L [8].

Seawater intrusion is a global issue, exacerbated by increasing demand for fresh water in coastal zones and predisposed of rising sea levels and changing climate [9]. There are many approaches on sea level rise study, direct measurement on sea level change by IPCC [10], study based on satellite altimetry [11] and study based on saline intrusion [12]. Results based on satellite altimetry [13] show that some sea level in East Malaysian coast such as Cherating, Pekan and Terengganu has sea level rise 3 to 4 mm/year. A study conducted by [14] showed that most of the tidal ranges are usually highest during spring tides and lower during neap tides. In the mixed tides, the diurnal and semidiurnal oscillations are both important factors and the tide is characterized by a large inequality in the high water heights, low water heights or both. Normally, there are two high and two low waters each day but occasionally the tide may become diurnal. However, some of the water quality parameters such as calcium, chloride, magnesium, potassium and sodium are useful chemical analyses to confirm conductivity readings. In [15] stated that increase of high tides has influenced the movement of seawater further to the upstream and affected salinity and total dissolve solids concentrations in the river. This is due to the concentration of high dissolved salts mainly consisting of sodium, chloride and magnesium composition in the seawater. Physiochemical parameters such as total dissolve solids (TDS), dissolve oxygen (DO), salinity, electrical conductivity (EC), turbidity and pH are effective in assessing of water quality due to sea level rise [16, 12]. As a finding of their study, in [17] stated that sea water intrusion were confirmed based on high level of chlorides in their study area a few kilometers from the sea in north of Semarang, Indonesia.

The declination of some water quality parameters are caused by an influx of freshwater into the ocean contributed by rainfall, melted glaciers and ice [12]. Freshwater addition into ocean was lead to salinity dilution [18, 12]. As salinity decreases, electrical conductivity and TDS are also decreases. This is due to linear relationship between salinity, electrical conductivity, TDS and makes their values varied spatially [19-20]. The decreased of pH trend toward upstream show that the river water became more acidic when further away from the sea [21]. It has a linear relationship with salinity [22]. As salinity decreases towards upstream and river water became more acidic. Therefore, a water quality assessment with respect to sea level rise impact at Marang and Paka Rivers are carried out in this study to determine water quality trend variations of spatial and temporal as well as the potential factors that contributing to this variations. The main objective of the study is to conduct a comparative study on water quality parameters of Marang and Paka Rivers between 2012 to 2015 and 2006 to 2012 wells monitoring assessment as they are can be used and serves as sea level rise indicator.

2. METHODOLOGY

2.1. Sampling Stations and the Study Area

Marang and Paka Rivers were chosen in this study as the two rivers that are affected by high and low tides, they located at Marang and Kemaman districts of Terengganu, Malaysia. Water sampling was carried out along these two rivers on 13 November 2012 and was repeated on 25 November 2015. Both samplings were conducted during Northeast monsoon period. During this period, the eastern part of Peninsular Malaysia received heavy rainfall and relatively low sea surface temperature [23, 6]. Seven sampling stations were selected from upstream to downstream in this water quality assessment during first and second samplings. Total often sampling stations were carried out during second sampling at Marang River, but maintained seven sampling stations at Paka River (Fig. 1). The first station is located at the estuary, where the meeting point between the rivers and the South China Sea. The last station is located at upstream where this area is less disturb by tidal activities. Each station is 2km apart, the total sampling distance along this study as approximately 18 to 20 km. In this study, tidal activities are considered as one of the factors that influenced river water quality of the river. Sampling is done twice where the first sampling was during low tide; the second sampling was during high tide. Both samplings were done at the same location according to the coordinate pinpointed by Global Positioning System (GPS). A secondary data of nine water quality parameters from the eleven wells such as Ca, Na, Mg, Fe, Cl, EC, TDS, TSS and pH were provided from the Malaysian Geo Science and Mineral Department for the six years period (2006 to 2012). The selection of these parameters is limited to parameters that related to the activities/reaction with seawater. The location of well is situated along the coastal of the Terengganu [27].

2.2. Measurement of in Situ Parameters

Parameters such as DO, EC, TDS, salinity, pH and turbidity were measure using YSI 556 Handheld Multiparameter meter. Turbidity was measured using 2100Q Portable Turbidimeter. To get a more accurate reading, the instruments were calibrated before measurements.

2.3. Statistical Analysis

Two-way t-test was used to determine the significant difference between two samples [24]. For each parameter, the two-way t-test was performed twice. Firstly, it was performed by using low tide 2012 and 2015 data samples. Secondly, it was performed on high tide 2012 and 2015 data samples. The outcome for the two-sample t-test is p-value that will be used to determine either the null hypothesis should be accepted or failed to be accepted. The significance level established for this study is 0.05. Samples with p-value more than significance level (0.05) should accept null hypothesis, meanwhile samples with p-value less than significance level (0.05) has fail to accept null hypothesis [25-26]. The first null hypothesis for the first two-sample t-test is stating that there is no mean difference between parameter readings during low tide 2012 and 2015. Meanwhile, the second null hypothesis is stating that there is no mean difference between parameter readings during high tide 2012 and 2015.

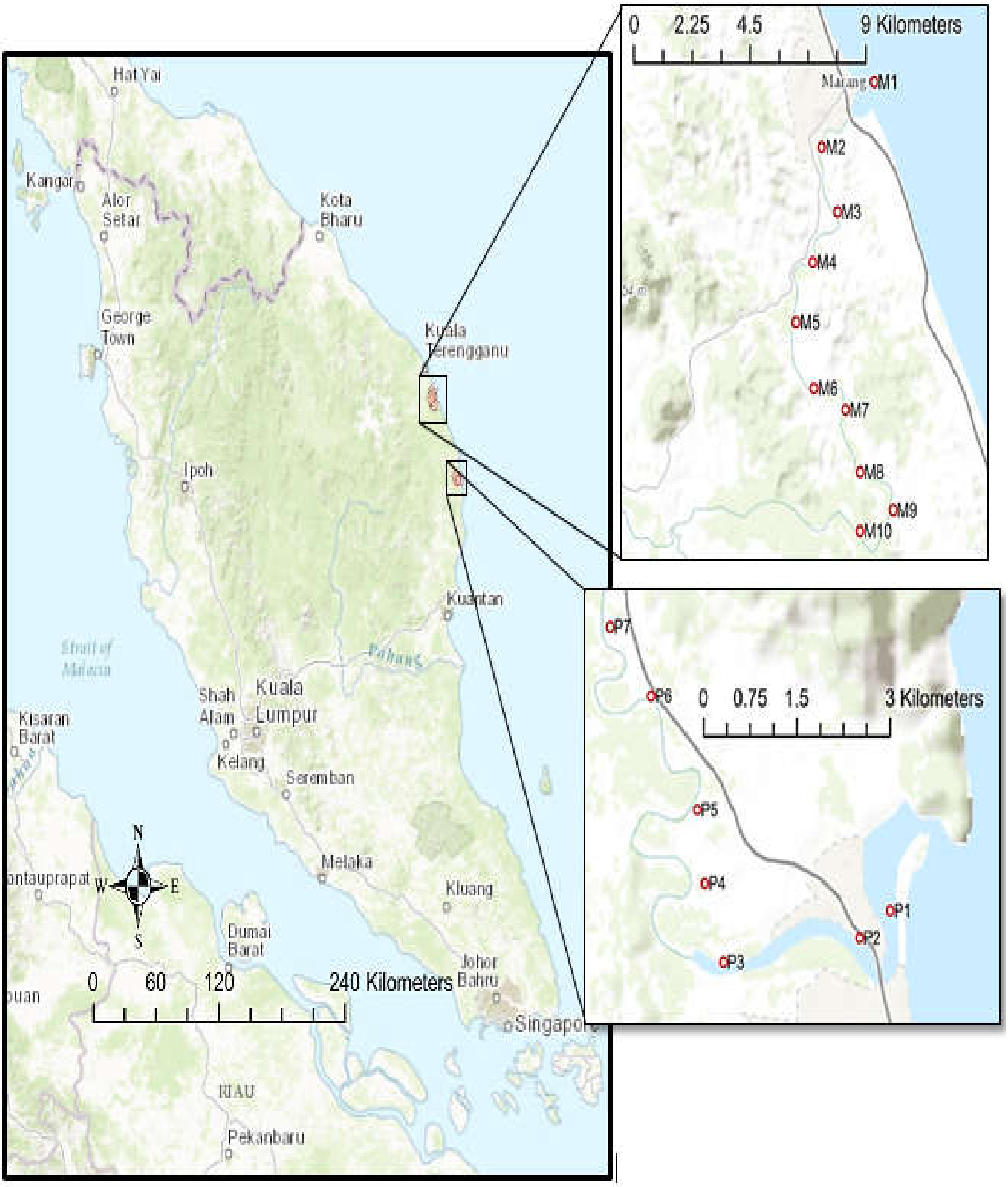

Fig.1. A map showing the location of sampling stations along Marang (m) and Paka (p) Rivers

3. RESULTS AND DISCUSSION

3.1. Water Quality Analysis

Six physicochemical water quality parameters such as DO, EC, TDS, salinity, pH and turbidity were analyzed to determine their water quality concentration of the Marang and Paka Rivers based on temporal and spatial variations. Nine of secondary data water quality under wells monitoring, such as Na, Ca, Mg, Fe, Cl, TSS, TDS, pH and EC were evaluated for their pattern.

3.2. Water Quality of Marang River (M)

Low tide 2012, salinity was ranging from 9.32 to 0.49 ppt with average of 3.26 ppt and was ranging from 13.1 to 0.84 ppt with average of 4.13 ppt during high tide. Low tide 2015, salinity was ranging from 10.22 to 0.57 ppt with average of 4.26 ppt, and was ranging from 25.36 to 0.68ppt with average of 9.37 ppt during high tide. Low tide2012, EC reading was ranging from 15432 to1203 µS/cm with average of 6309µS/cm and was ranging from 23685 to 1755 µS/cm with average of 8499µS/cm during high tide. Low tide 2015, EC reading was ranging from 17541 to 1070 µS/cm with average of 6407µS/cm and was ranging from 44027 to 1478 µS/cm with average of 16975 µS/cm during high tide. Low tide 2012, TDS was ranging from 9,276 to 745 mg/L with average 3,832 mg/L and was ranging from 14,336.8 to 1,094 mg/L with average 5,172 mg/L during high tide. Low tide 2015, TDS was ranging from 10,430 to 900 mg/L with average 4,091 mg/L and was ranging from 25,970 to 900 mg/L with average 10,046 mg/L during high tide. Low tide 2012, DO reading was ranging from 4.65 to 4.11 mg/L with average of 4.21 mg/L and was ranging from 6.36 to 4.01 mg/L with average of 4.66 mg/L during high tide. Low tide 2015, DO reading was ranging from 2.94 to 2.32 mg/L with average of 2.62 mg/L and was ranging from 3.26 to 2.45 mg/L with average of 3.03 mg/L during high tide. In general, distribution trend of DO is decreasing from M1 to M10. It has concurred trend to salinity. Low tide 2012, pH reading was ranging from 7.34 to 5.96 with average of 6.61 and was ranging from 8.5 to 6.09 with average of 7.02 during high tide. High tide 2015, pH was ranging from 8.22 to 5.55 with average of 7.11 and was ranging from 8.22 to 5.89 with average of 7.59 during low tide. Low tide 2012, turbidity was ranging from 10.22 to 70.68 NTU with an average reading of 35.86 NTU and was ranging from 12.42 to 88.60 NTU with an average of 45.80 NTU during high tide. Low tide 2015, turbidity was ranging from 15.80 to 86.87 NTU with an average of 42.54 NTU and was ranging from 18.18 to 92.2 NTU with an average of 85.56 NTU during high tide (Table 1 and 2).

3.3. Statistical Analysis of Marang River (M)

Salinity, EC and TDS parameters were showing similar distribution trend, which are declining from M1 to M10. The similar trend suggests an association between these parameters. Two-sample t-test ($P < 0.05$) was performed on these three parameters by using low tide 2012 and 2015 as data samples. It revealed that salinity, EC and TDS readings show no significant difference during low tide 2012 and 2015. The p-value for each parameter is 0.552, 0.5182 and 0.4264 respectively. Two-sample t-test ($P < 0.05$) were also performed on high tide 2012 and and 2015 data samples. The results revealed that salinity (P = 0.0992), EC (P = 0.0992) and TDS (P = 0.116) readings during high tide 2012 and 2015 were not significantly different. However, salinity, EC and TDS reading amplitudes for 2012 are greater than 2015 and significantly shown at M1 and M2. These results emphasized a slight increase in salinity, EC and TDS from 2012 to 2015 but it is not significant enough as had been revealed by two-sample t-test. DO in 2012 were rapidly increased from M1 to M3 and then slowly decreased until M10. During 2015, DO was slowly decreases from M1 to M10. Two-sample t-test ($P < 0.05$) between low tide 2012 and 2015 as well as high tide 2012 and 2015 revealed that the DO readings of low tide and high tide between 2012 and 2015 were significantly different ($P < 0.0001$). The distribution of pH trend was gradually decreasing from M1 to M10 during low and high tides in 2012 and 2015. Two-sample t-test on pH readings during low tide 2012 and 2015 show that there is significant differences (P = 0.0199) between the pH reading during 2012 and 2015. However, two-sample t-test ($P < 0.05$) failed to reject that there is no significant difference (P = 0.1133) between pH readings during high tide for both years. For turbidity, two-sample t-test ($P < 0.05$) performed on low tide 2012 and 2015 data samples emphasized that the low tide turbidity reading during 2012 and 2015 is significantly difference (P = 0.008). Two-sample t-test on high tide data samples is also showing a significant different (0.0119) between the turbidity readings during high tide 2012 and 2015 data samples.

Table 1. Concentration of six water quality parameters between low and high tides 2012 of the Marang River

Year	2012																			
Tide	Low Tide										High Tide									
Station	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
W.Q. Parameter																				
Salinity	9.32	8.98	8.62	6.70	6.19	5.80	4.98	4.08	2.29	0.49	13.1	11.86	10.35	9.58	7.85	6.05	4.80	3.65	2.89	0.84
Conductivity	15432	12500	10900	8580	7022	6980	5250	3580	1568	1203	23685	21580	18300	1540	1250	1070	8450	7450	4275	1755
TDS	9276	8262	7985	6546	5687	4853	3275	2345	1587	745	14336	12828	10265	8648	6028	5645	4820	3468	2472	1094
DO	4.41	4.50	4.65	4.30	4.26	4.24	4.22	4.20	4.18	4.11	6.02	6.24	6.36	6.10	5.92	5.25	4.48	4.28	4.04	4.01
pH	7.34	7.01	6.86	6.42	6.02	5.87	5.55	5.28	5.62	5.96	8.5	8.2	7.8	7.5	7.3	7.01	6.8	6.6	6.3	6.09
Turbidity	10	15	29	34	39	42	48	56	62	70	12	23	38	41	48	52	66	70	75	88.6

Table 2. Concentration of six water quality parameters between low and high tides 2015 of the Marang River

Year	2015																			
Tide	Low Tide										High Tide									
Station W.Q. Parameter	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Salinity	10.22	9.38	8.65	7.15	6.78	5.20	4.05	2.87	1.25	0.57	25.36	22.59	18.98	15.65	13.42	10.22	8.45	6.87	2.87	0.68
Conductivity	17541	15254	13748	10250	8450	7135	7628	5500	3250	1070	44027	35680	28830	25660	18250	16560	12458	8632	3250	1478
TDS	10430	8328	6790	5287	4830	4145	3828	2460	1468	900	25970	23426	20827	16926	102468	8732	6945	5428	2245	900
DO	2.94	2.80	2.75	2.71	2.66	2.58	2.51	2.43	2.39	2.32	3.26	3.11	2.92	2.84	2.76	2.67	2.60	2.56	2.51	2.45
pH	8.22	8.01	7.83	7.61	7.22	7.01	6.82	6.22	5.91	5.55	8.22	8.01	7.87	7.56	7.28	6.88	6.57	6.28	6.01	5.89
Turbidity	15.8	22.6	28.4	33.6	46.7	59.4	62.6	68.9	75.4	86.7	18.8	26.6	32.8	42.6	55.9	68.5	77.4	82.8	87.5	92.5

3.4. Water Quality of Paka River (P)

Salinity values were ranging from 1.67 to 0.01 ppt with average of 0.31 ppt during low tide 2012. During high tide 2012, it was ranging from 3.48 to 0.01 ppt with average of 0.77 ppt. Low tide 2015, salinity values were ranging from 5.94 to 0.02 ppt with average of 1.25 ppt; during high tide 2015 were ranging from 8.15 to 0.03 ppt with average of 1.34 ppt. Low tide 2012, EC readings were ranging from 3470 to 33 µS/cm with average of 652 µS/cm; high tide 2012 ranging from 6810 to 35 µS/cm with average of 1549 µS/cm. Low tide 2015 were ranging from 13,118to 56µS/cm with average of 2,712 µS/cm; during high tide were ranging from 18,259 to 68 µS/cm with average of 2,986 µS/cm. Low tide 2012, TDS values were ranging from 2.1 to 0.022 mg/L with average of 0.4 mg/L and were ranging from 4.17 to 0.021 mg/L with average 0.95 mg/L during high tide. TDS values during low tide 2015 were ranging from 6,905 to 35 mg/L with average 1,503 mg/L and from 10,244 to 42 mg/L with average reading of 1,695 mg/L during high tide. DO were ranging from 5.65 to 4.9 mg/L with average of 5.25 mg/L during low tide 2012 and from 5.85 to 4.71 mg/L with average 5.28 mg/L during high tide. Low tide 2015, DO values were from 2.68 to 3.36 mg/L with average of 3.09 mg/L and from 2.36 to 3.72 mg/L with average of 3.27 mg/L during high tide. In general, distribution of DO trend was decreased from P1 to P7. The 2012 pH values were from 6.43 to 5.19 with average of 5.79 during low tide and from 6.8 to 5.54 with average of 6.00 during high tide. pH values during low tide 2015were from 6.82 to 5.55 with average of 6.05 and from 6.7 to 5.46 with average of 5.95 during high tide 2015. Finally, turbidity values were ranging from 10.22 to 71.76 NTU with an average of 35.57 NTU during low tide 2012 and from 2.80 to 61.06 NTU with an average of 27.86 NTU during high tide. During low tide 2015, turbidity values were from 39.6 to 119 NTU with an average of 81.7 NTU and from 22.2 to 144.7 NTU with an average of 98.7 NTU during high tide (Table 3 and 4).

3.5. Statistical Analysis of Paka River (P)

The readings trend of salinity, EC and TDS parameters were decreasing from upstream (P1) to downstream (P7) during high and low tides for both years. Two-sample t-test ($P < 0.05$) was performed during low and high tides data samples obtained during 2012 and 2015 for salinity, EC, TDS and pH parameters. The test were revealed no significance difference between the readings of low tides 2012 and 2015 where the p-value for salinity, EC, TDS and pH were 0.2862, 0.2888, 0.1374 and 0.3846 respectively. Two-sample t-test also shown that the readings of salinity, EC, TDS and pH during high tides 2012 and 2015 were not significantly different. P-value for salinity, EC, TDS and pH were 0.6597, 0.6100, 0.2595 and 0.8385 respectively. DO shows a steady reading with a small variation between stations, two-sample t-test ($P < 0.05$) determined that there are significantly differences between DO readings for low tide data samples ($P < 0.0001$) and high tide data samples ($P < 0.0001$) during 2012 and 2015. Turbidity readings show an inclining trend from P1 to P7 for both years. Two-way t-test ($P < 0.05$) on turbidity readings revealed a significant difference of turbidity readings between 2012 and 2015 on both low tide ($P = 0.0052$) and high tide (0.0409).

Table 3. Concentration of six water quality parameters between low and high tides 2012 of the Paka River

Year	2012													
Tide	Low Tide							High Tide						
Station	1	2	3	4	5	6	7	1	2	3	4	5	6	7
W.Q. Parameter														
Salinity	1.67	1.48	1.26	0.89	0.64	0.15	0.01	3.48	2.85	2.18	1.65	1.08	0.6	0.01
Conductivity	3470	2648	1680	800	268	88	33	6810	4865	2854	2286	1074	125	35
TDS	2.1	1.85	1.26	0.78	0.10	0.078	0.022	4.17	3.65	2.10	1.78	1.06	0.12	0.021
DO	5.65	5.58	5.49	5.32	5.24	5.16	4.91	5.85	5.72	5.48	5.24	5.03	4.99	4.71
pH	6.43	6.28	6.02	5.87	5.65	5.48	5.19	6.8	6.6	6.4	5.99	5.86	5.71	5.54
Turbidity	10	28	32	49	52	68	71	2.80	13	28	32	48	58	61.06

Table 4. Concentration of six water quality parameters between low and high tides 2015 of the Marang River

Year	2015													
Tide	Low Tide							High Tide						
Station	1	2	3	4	5	6	7	1	2	3	4	5	6	7
W.Q. Parameter														
Salinity	5.94	5.32	3.62	2.28	1.82	0.24	0.02	8.15	6.82	5.91	3.87	2.69	1.0	0.03
Conductivity	13118	10246	8453	4289	2782	652	56	18259	14876	965	658	435	225	68
TDS	6905	4376	2698	1548	656	110	35	10244	8260	4858	2845	1286	345	42
DO	3.36	3.29	3.27	3.18	3.04	2.98	2.68	3.72	3.48	3.22	2.98	2.78	2.64	2.36
pH	6.82	6.48	6.35	6.21	5.99	5.86	5.55	6.7	6.4	6.0	5.92	5.78	5.65	5.46
Turbidity	39.6	78	81	89	92	101	119	22	38	52	78	84	120	144.7

3.6. Water Quality of Monitoring Wells

The results of nine water quality parameters from 2006 to 2012 water quality monitoring wells are stated in Table 5. Sampling and analysis of each parameter has been carried twice a year, sampling time is adjusted based on the monsoon season. Unit of each parameter is ppm or equal to mg/l, except for EC (µS/cm). The result of the analysis shows that each parameter has increased annually or at least has increased in the past 6 years (Table 5).

Table 5. Nine of water quality parameters result based on 2006 to 2012 wells monitoring

Date	Na	Ca	Mg	Fe	Cl	TSS	TDS	pH	EC (µS/cm)
May 2006	56.00	14.00	2.10	1.60	23.00	274.00	216.00	7.20	292.00
Nov 2006	53.00	16.00	1.60	1.40	31.00	266.00	246.00	7.20	305.00
Feb 2007	50.00	15.50	1.10	1.40	30.50	288.00	225.00	5.30	330.00
Feb 2008	43.00	15.00	3.10	2.00	28.00	288.00	158.00	7.30	349.00
June 2008	31.00	16.00	3.40	2.10	18.00	280.00	163.00	7.60	235.00
Mac 2009	41.00	17.00	4.90	4.10	32.00	334.00	328.00	8.80	482.00
Oct 2009	37.00	14.00	3.20	2.10	30.00	266.00	262.00	7.60	359.00
April 2010	48.00	13.00	3.20	2.60	25.00	262.00	202.00	7.80	307.00
Nov 2010	50.00	11.00	3.00	2.20	27.00	254.00	244.00	7.60	323.00
May 2011	53.00	28.00	3.50	2.40	25.00	284.00	268.00	8.20	308.00
June 2012	62.00	16.00	3.70	2.00	36.00	278.00	270.00	7.30	385.00

Noted: All the units in mg/L except for pH and EC

4. CONCLUSION

Six water quality parameters were selected in relation for the qualitative study on sea level rise. Typically, the concentration of the three water quality parameters (salinity, conductivity and DO) are higher during 2012 and 2015 high tides. These three water quality parameters have increased their concentration during 2015 compared to 2012. Generally, Marang River has a higher concentration than the Paka River for both low and high tides and between 2012 and 2015. This shows that salinity, conductivity and TDS parameters have shown that the presence of sea movement to land through the two rivers in 2015 is increasing compared to 2012.

The effect of high turbidity and low DO of Paka and Marang Rivers are could be the effect of pollution due to anthropogenic activities in the downstream of the rivers. Low pH was due to sand mining activity in the downstream area also indicated by low DO but increase of turbidity, three to four sand mining activities have been traced in this study. Most of parameters reading on the Paka River are lower than that in the Marang River. It is likely that the flow movement of the Paka River is protected by beach morphology from the tidal movement of the South China Sea.

Results from the eleven wells water quality data shows that the value of each parameter was increased during dry season and it drops during rainy season. It can be shown that most of the parameters increased during March 2009, it seems as the peak of dry period. Tidal activity, especially during high tide will be move far into the land through the river systems. Due to the above condition, the readings of nine water quality parameters from the eleven wells were increased between 1.4 to 43.2% from May 2006 to June 2012. The evidence of global warming coupled with heavy storm and flood phenomenon during Northeast monsoon season was lead to the rising qualitatively sea level of the South China Sea.

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