FACULTY OF RESOURCE SCIENCE AND TECHNOLOGY

Water Quality at Tanjung Bajong coast

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List of Abbreviations

AAS	Atomic Absorption Spectrophotometer
APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
CO_2	Carbon Dioxide
DO	Dissolved Oxygen
DOE	Department of Environment, Malaysia
EPA	Environmental Protection Agency
GPS	Global Positioning System
H_2O	water
MWQS	Marine Water Quality Criteria and Standards
NTU	Nephelometric Turbidity Unit
PSU	Practical Salinity Unit
SPSS	Statistical Package Social Science
TSS	Total Suspended Solids

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Water Quality at Tanjung Bajong coast, Sebuyau, Sarawak

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ABSTRACT

Coastal water samples were collected from 6 sampling stations in Tanjung Bajong coast, Sebuyau, Sarawak. Temperature, transparency, turbidity, depth, pH, conductivity, dissolved oxygen, and salinity were measured directly *in-situ* while water samples were collected and analyzed in the laboratory for total suspended solids (TSS), BOD_5, chlorophyll *a*, orthophosphate, nitrate, nitrite, and 6 heavy metal concentrations which are nickel (Ni), arsenic (As), lead (Pb), manganese (Mn), zinc (Zn), and copper (Cu). The ranges for the physico- chemical parameters were 29.6 - 35.1 °C for temperature, 90.0 - 295.0 NTU for turbidity, 18.3 - 23.8 PSU for salinity, 6.49 - 10.38mg/L for DO, 0.6 -1.4m for depth, 28.48 - 34.61µS for conductivity, 7.50 - 7.77 for pH, 10 -13mm for transparency, 247.22 - 796.89mg/L for TSS, 2.73 - 6.70mg/L for BOD_5, 5.07 - 10.43mg/L for chlorophyll *a*, 0.02 - 0.23mg/L for orthophosphate, 0.03 - 0.043mg/L for nitrate, and 0.013 - 0.016mg/L for nitrite. The heavy metals (mg/L) were 0.007 - 0.037 for Zn, 0.0711 - 0.2862 for Mn while Ni, As, Pb and Cu were under detectable limit. Tanjung Bajong coast can be classified as Class E according to MWQS.

Keyword: coastal, *in-situ*, heavy metals, MWQS

ABSTRAK

Sampel air telah diambil daripada 6 stesen di persisiran Tanjung Bajong,Sebuyau, Sarawak. Suhu, kejernihan, kekeruhan, kedalaman, pH, konduktiviti, oksigen terlarut (DO), dan saliniti diukur in-situ manakala sampel air diambil untuk analisis di dalam makmal. Antaranya ialah jumlah ampaian pepejal (TSS), BOD_5, klorofil a, ortofosfat, nitrat, nitrit, dan kepekatan 6 logam berat iaitu Ni, As, Pb, Mn, Zn, dan Cu. Julat parameter fiziko-kimia air yang diukur ialah 29.6 - 35.1 °C (suhu), 90.0 - 295.0 NTU (kekeruhan), 1.83 - 2.38 PSU (saliniti), 6.49 - 10.38mg/L (DO), 0.6 -1.4m (kedalaman), 28.48 - 34.61µS (konduktiviti), 7.50 - 7.77 (pH), 10 -13mm (kejernihan), 247.22 - 796.89mg/L (TSS), 2.73 - 6.70mg/L (BOD_5), 5.07 - 10.43mg/L (klorofil a), 0.02 - 0.23mg/L (ortofosfat), 0.03 - 0.043mg/L (nitrat), 0.013 - 0.016mg/L (nitrit). Julat kepekatan logam berat (mg/L) ialah 0.007 - 0.037 (Zn), 0.0711 - 0.2862 (Mn), manakala Ni, As, Pb, dan Cu ialah di bawah had pengenalpastian. -0.0144 hingga -0.0097 (Cu). Berdasarkan MWQS, persisiran Tanjung Bajong boleh dikategorikan dalam Kelas E.

Kata kunci: persisiran,in-situ, logam berat, MWQS

INTRODUCTION

Coastal zone is the interface where the land meets the oceans, encompassing shoreline environments as well as adjacent coastal waters. Its components can include river deltas, coastal plains, wetlands, beaches and dunes, reefs, mangrove forests, lagoons, and other coastal features. According to Shahrizaila (1993), the coastal zone is broadly defined as the areas where terrestrial and marine processes interact. These include the coastal plains, deltaic areas, coastal wetlands, estuaries and lagoons.

Water quality is a term used to express the suitability of water to sustain various uses or processes. Any particular use will have certain requirements for the physical, chemical or biological characteristic of water. For example, limits on the concentrations of toxic substances for drinking water use, or restrictions on temperature and pH ranges for water supporting invertebrate communities. A wide range of natural and human influences affects water quality. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and quality of water available.

Water quality of many rivers in the world has been investigated to gain more understanding on the impact of agriculture, aquaculture, sewage, household and industrial effluents on the receiving water bodies (Ling *et al.*, 2009). However, there are limited studies that relate to water quality and heavy metals in Tanjung Bajong coastal area. This study was conducted at Tanjung Bajong, Sebuyau, Sarawak.

The objectives of the study were:

1. To determine the selected physico-chemical parameters of the water at Tanjung Bajong area.

2. To determine the status of water quality at Tanjung Bajong coastal area.

3. To establish a baseline data for water quality in Tanjung Bajong coastal area.

LITERATURE REVIEW

2.1 Water quality parameters

Water quality can be divided into physical, chemical or biological parameters. There are several parameters often used for testing the water bodies such as lakes, rivers, and coastal area. Water quality parameters also can be divided into *in-situ* and *ex-situ* parameters. The *in-situ* parameters are temperature, water current, turbidity, depth, pH, conductivity, dissolved oxygen (DO), and salinity. The *ex-situ* parameters such as nutrients and heavy metals were measured in the laboratory. Since this study will be focused on the coastal water bodies, the coastal or estuarine water quality might be slightly different from freshwater water quality.

2.1.1 Salinity

Salinity is the total amount of solid material dissolved in water including dissolved gases but excluding dissolved organic substances (Alan *et al*., 2008). Salinity does not include fine particles being held in suspension (turbidity) or solid material in contact with water because these materials are not dissolved. Salinity is the ratio of the mass of dissolved substances to the mass of the water sample. The salinity of seawater is typically about 3.5%, about 220 times saltier than freshwater (Alan *et al*., 2008). Salinity is often expressed in parts per thousand (‰) and are effectively parts per thousand by weight. Salinity values, however, lack units because the salinity of a water sample is determined as the ratio of the electrical conductivity of the sample to the electrical conductivity of a standard. Thus, salinity values are sometimes reported in “p.s.u” or practical salinity units, which are equivalent to parts per thousand.

2.1.2 Temperature

According to Alan *et al.* (2008), the ocean temperatures have a far narrower range than temperatures on land. The minimum surface temperature of the deep ocean is seldom much below -2°C (28.4 °F) and the maximum surface temperature seldom exceeds 32°C (89.6°F), except in some shallow-water coastal regions, where the temperature may reach 40°C (104°F). However, on land, extremes in temperatures have ranged from -88°C (-127°F) to 58°C (136°F), which represents a temperature range more than four times greater than that experienced by the ocean (Alan *et al*., 2008). This phenomenon is called as the continental drift. Furthermore, the ocean has a smaller daily, seasonal and annual temperature range than that experienced on land, which provides a stable environment for marine organisms. In addition, the small daily and seasonal temperature variations are confined to ocean surface waters and decrease with depth, becoming insignificant throughout the deeper parts of the ocean. At ocean depths that exceed 1.5 kilometers, for example, temperatures however around 3°C (37.4°F) year-round, regardless of latitude (Alan *et al*., 2008).

2.1.3 Total suspended solids (TSS)

Total suspended solids are solid materials, such as organic and inorganic materials, that are suspended in the water body. It can lower water quality when it becomes high concentration in water by absorbing light. It will lessen the ability of water to hold oxygen that is essential for aquatic living organisms and it will make the water become warmer than before. It is because the aquatic plants also will receive less light, eventually it will affect the production of photosynthesis which is decreasing in production of oxygen. Also, suspended solids can affect life in other ways by clogging the fish gills, reducing the growth rates, resistance to disease will be decreasing, and it prevent the development of egg and larval. It is because the particles that are settled out can smother the fish eggs and those of aquatic insects, as well as suffocate newly-hatched larvae. Total suspended solids can be measured in mg/L by using the filtration process.

2.1.4 Dissolved oxygen

Dissolved oxygen measures the amount of oxygen dissolved in an aqueous solution or in water bodies. Dissolved oxygen is one of the important water quality parameters as it is an absolute requirement for the metabolism of aerobic organisms and it will influence the inorganic chemical reactions. The amount of dissolved oxygen in water depends on the temperature. The amount that can be dissolved in pure water is inversely proportional to the temperature of water. Therefore, water will become warmer as a result of lesser amount of dissolved oxygen in water. Atmospheric pressure also influences the amount of dissolved oxygen. So, it is important to have knowledge on the solubility and dynamics of oxygen distribution in order to interpret the biological and chemically processes that occurred in the water bodies.

2.1.5 Conductivity

Conductivity is a measurement of the ability of an aqueous solution to carry an electric current. An ion is an atom of an element that has gained or lost an electron which will create a negative or positive state in a solution. There are several factors that determine the conductivity in water such as the concentration or number of ions, mobility of ions, oxidation state, and temperature of the water. Also, the conductivity can be used to determine a number of applications that are related to water quality. There are determining the mineralization, the amounts of chemical reagents or treatment chemicals to be added to water sample, estimating the sample size that necessary for other chemical analyses, and able to notice any variation or changes in water bodies.

2.2 Heavy Metals

Heavy metal concentrations in aquatic ecosystems are usually monitored by measuring their concentrations in water, sediments and biota (Camusso *et al.*, 1995 as cited by M. Öztürk *et al.*, 2009), which generally exist in low levels in water and attain considerable concentration in sediments and biota (Namminga and Wilhm, 1976 as cited by M. Öztürk *et al.*, 2009). Heavy metals including both essential and non-essential elements have a particular significance in ecotoxicology, since they are highly persistent and all have the potential to be toxic to living organisms (Storelli *et al.*, 2005 as cited by M. Öztürk *et al.*, 2009). Some heavy metals are active ingredients in agrochemicals, others are present as contaminants (Tyagi and Mehra, 1990; Ochieng' *et al.*, 2007; Food and Waterwatch, 2008 as cited by P.M. Njogu *et al.*, 2011). Heavy metals may accumulate unnoticed in the aquatic environment to toxic levels. They are partitioned among the various aquatic compartments and may occur in dissolved, particulate and complex forms. The main processes governing their distribution and partition are dilution, dispersion, sedimentation and adsorption /desorption (Massoud, 2003). Heavy metals such as copper, iron, chromium and nickel are essential metals since their play an important role in biological systems, whereas cadmium and lead are non-essential metals, as they are toxic, even in trace amounts (Fernandes *et al.*, 2008 as cited by M. Öztürk *et al.*, 2009).

2.3 Malaysia Marine Water Quality Criteria and Standard

Malaysia Marine Water Quality Criteria and Standard (MWQS) (DOE, 2011) is use for classification of coastal and estuarine water in Malaysia (Table 1). It consists of several physico-chemical parameters to be used as the indicator or standard to classify the coastal water and estuarine.

Table 1: Malaysia Marine Water Quality Criteria and Standards (MWQS)

Parameter	CLASS 1	CLASS 2	CLASS 3	CLASS E
BENEFICAL USES	Preservation, Marine Protected areas, Marine Parks	Marine Life, Fisheries, Coral Reefs, Recreational and Mariculture	Ports, Oil & Gas Fields	Mangroves Estuarine & River-mouth Water
Temperature (°C)	≤ 2°C increase over maximum ambient	≤ 2°C increase over maximum ambient	≤ 2°C increase over maximum ambient	≤ 2°C increase over maximum ambient
Dissolved oxygen (mg/L)	>80% saturation	5	3	4
Total suspended solid (mg/L)	25 mg/L or ≤ 10% increase in seasonal average, whichever is lower	50mg/L (25 mg/L) or ≤ 10% increase in seasonal average, whichever is lower	100 mg/L or ≤ 10% increase in seasonal average, whichever is lower	100 mg/L or ≤ 30 % increase in seasonal average, whichever is lower
Oil and grease (mg/L)	0.01	0.14	5	0.14
Mercury* (µg/L)	0.04	0.16 (0.04)	50	0.5
Cadmium (µg/L)	0.5	2 (3)	10	2
Chromium (VI) (µg/L)	5	10	48	10
Copper (µg/L)	1.3	2.9	10	2.9
Arsenic (III)*	3	20 (3)	50	20 (3)

(µg/L)				
Lead (µg/L)	4.4	8.5	50	8.5
Zinc (µg/L)	15	50	100	50
Cyanide (µg/L)	2	7	20	7
Ammonia (unionized) (µg/L)	35	70	320	70
Nitrite (NO_2) (µg/L)	10	55	1,000	55
Nitrate (NO_3) (µg/L)	10	60	1,000	60
Phosphate (µg/L)	5	75	670	75
Phenol (µg/L)	1	10	100	10
Tributyltin (TBT) (µg/L)	0.001	0.01	0.05	0.01
Faecal coliform (Human health protection for seafood consumption) - most Probable Number (MPN)	70 faecal coliform $100mL^{-1}$	100 faecal coliform $100mL^{-1}$ & (70 faecal coliform $100mL^{-1}$)	200 faecal coliform 100mL-1	100 faecal coliform $100mL^{-1}$ & (70 faecal coliform $100mL^{-1}$)
Polycyclic Aromatic Hydrocarbon (PAHs) ng/g	100	200	1000	1000

MATERIAL AND METHODS

3.1 Study site

The study was conducted at Tanjung Bajong coastal area that was located close to small town, Sebuyau. Along the way to Tanjung Bajong, there are a lot of agricultural activities such as paddy plantation. Farmers along the coast used herbicides, pesticides, insecticides, and fungicides in their agricultural field. The boat factory used chemical that contain heavy metals in making fishermen boat and all these chemical were released in the water bodies. Other than that, there are mangrove forests and a quarry along the Tanjung Bajong coastal area. Water samples were collected from six sampling stations along the Tanjung Bajong coastal area that covered a distance of approximately 10 kilometers (Figure 1). Six sampling stations were selected from the outer part of the Tanjung Bajong coast (Tanjung Melaban) towards Sebuyau town. Weather condition, sampling area or location, coordinates of each station, and data for *in-situ* parameters were recorded. The coordinates of each station were recorded by using the Global Positioning System (GPS) (Table 2).

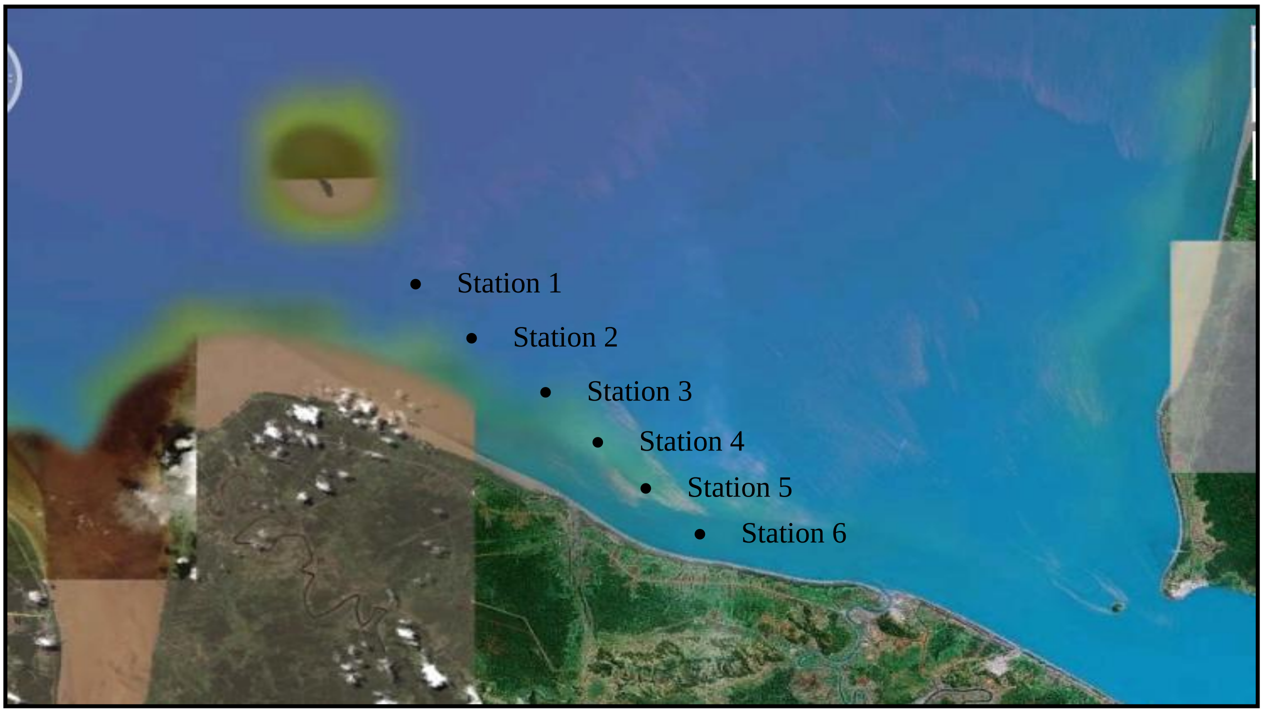

Figure 1: Sampling stations at Tanjung Bajong coast. Sources: Sungai Bajong, Sarawak, Malaysia (2011)

Table 2: Sampling stations and the GPS coordinate

Stations	**GPS reading**
Station 1	N 01° 34.989’ E 110° 48.134’
Station 2	N 01°34.900’ E 110°48.457’
Station 3	N 01°34.685’ E 110° 48.861’
Station 4	N 01°34.522’ E 110°49.165’
Station 5	N 01°33.427’ E 110° 50.693’
Station 6	N 01°32.308 E 110°52.333’

3.2 Physico-chemical parameters of the water

Water parameters such as temperature, transparency, turbidity, depth, pH, conductivity, dissolved oxygen, and salinity were measured *in-situ*. All of these parameters were measured by using the Horiba multiprobe. Alternative equipments such as DO meter, pH meter, turbidity meter, depth finder, and refractometer were used if the Horiba multiprobe was not functioning well. For *ex-situ* parameters, water sample were collected by using the Van Dorn water sampler. The collected water was used for Total Suspended Solids (TSS), BOD_5, chlorophyll *a*, heavy metal and nutrient analysis. Water samples from Van Dorn water sampler were poured into 2L plastic bottle samples. Each bottle that contain water sample were labeled properly with a detailed description such as date, time, station, and number of replicates. Three replicates of water samples were taken for each water quality parameters.

3.3 Laboratory Analysis

3.3.1 Total Suspended Solids (TSS)

Analyses for TSS which is involving the filtration process was carried out in the laboratory. Glass fibre GF/C filter paper was soaked in distilled water before it was placed on a piece of aluminium foil individually. Then it was left drying in the oven at 103-105°C overnight. The filter paper was taken out after being kept in the oven overnight and being left a few minutes for cooling process in order to avoid fluctuation of the weight. Each filter paper was wrapped in aluminium foil individually and labeled. After calibration of the analytical balance, each of the wrapped filter paper was weighed and the initial weight was recorded. The filtration system had to be assembled first before undergo the filtration of water sample. The prepared filter paper was placed on the glass interpolate of the filter holder's rack using a pair of forceps. A 250 mL to 1 liter well-mixed water sample was filtered, the volume of sample to be filtered depends on the content of suspended solids in the water sample. Then, filter paper was removed from the filtration funnel and placed back in the aluminium foil. The wrapped filter paper was put in the oven at 103-105 °C overnight for drying process. For the next day, the filter paper was left out in room temperature for cooling process before being weighed. Its final weight was recorded and the value of TSS was calculated by using the following formula:

$$\text{TSS (mg/L)} = \frac{(A-B) \times 1000}{C}$$

Where A= final weight of filter paper

B= initial weight of filter paper

C= volume of water (L) filtered

3.3.2 Biochemical Oxygen Demand after 5 Days (BOD_5)

Water sample was collected and placed into the 300 mL glass stoppered bottle for each station. During sample collection, there was one precaution that had to be done that was to make sure there were no bubbles in the bottle. Then, the bottles were wrapped with aluminium foil after dissolved oxygen (DO) values was measured and recorded on the sampling day. The wrapped bottles were kept in the room temperature for five days at the laboratory. After five days, dissolved oxygen (DO) of the water samples in the BOD bottles was measured. Finally, the value of the BOD was calculated by using the following formula:

$$BOD_5 \text{ (mg/L)} = D_1 - D_5$$

Where D_1= initial DO measured on the sampling day (mg/L)

D_5 =DO value after 5 days incubation (mg/L)

3.3.3 Chlorophyll –*a* Analysis

Chlorophyll –*a* analysis were divided into several steps which were sample preparation, sample extraction, spectrophotometric measurement, and lastly the calculation of the value of the chlorophyll-*a*. Chlorophyll-*a* analysis was done in subdued light or semi-darkened room. Sample preparation steps involved the filtration process and water samples being filtered was filled into the top section of the filter unit up to 500mL. As the water was being filtered, 2-3 drops of magnesium carbonate suspension ($MgCO_3$) was added to prevent acidity on the filter and subsequent degradation of pigments in the extract. The amount of water sample being filtered was 1000mL or 1L. Filter paper then was removed and rolled with the rough side or the filtered substances on the inside after filtration process. Filter paper was folded with aluminium foil and kept into the dessicators.

For sample extraction, the filtered substances were grinded with mortar and pestle in approximately 5-6mL 90% aqueous acetone. All of the fluid in the mortar was placed into a capped test tube and made up the volume to 10mL by adding 90% acetone. The test tube folded with the aluminium foil was subsequently placed in a refrigerator for 4-18 hours. Then, the liquid extracts were transferred into the centrifuge tube and the solution was centrifuged for about 10 minutes under 3000 rpm. Lastly, the supernatant solution was used for the determination of optical density in a spectrophotometer. The maximum adsorption wavelength of chlorophyll *a*, *b* and *c* were 750nm, 664nm, and 630nm. It involved the calculation of the chlorophyll-*a* by using the formula as follow:

Chlorophyl *a* = $11.85E_{664} * 1.54E_{647} *0.08E_{630}$

Chlorophyl *b* =$21.03E_{647} *5.43E_{664}* 2.66E_{630}$

Chlorophyl *c* = $24.52E_{630}*1.67E_{664}*7.60E_{647}$

Where E was the absorption in the respective wavelength obtained above and Ca, Cb, and Cc were the amounts of chlorophyll (in µg/mL if a 1cm light path cuvette was used);

$$\text{Chl a (mg/m}^3) = C_x \times v / V \text{ (L)}$$

Where v was the volume of acetone in mL, V is the volume of seawater in liters and Ca, Cb, and Cc were the three chlorophylls that substituted for C in the above equation, respectively.

3.3.4 Nutrient analysis

The water samples were filtered before analysis of nutrient. The filtered water samples were stored in the refrigerator at 4°C or below if the samples were to be analyzed within 24-48 hours. However, for orthophosphate analyses, the sample was filtered first before keeping in deep freezer at -20 °C where it can last for six months. The sample was thawed to room temperature before the analysis was conducted (Hach, 2000). For orthophosphate analysis, the concentration of phosphorus was determined following the standard method 8048 (0-2.50 mg/L PO_3^{2-}). Orthophosphate reacted with molybdate in an acid medium to produce a molybdenum blue colour (Hach, 2000). Then, for the nitrate analysis, the concentration of nitrate was determined following the standard method 8192 (0.01-0.4

mg/L NO_3-N). Cadmium metal reduces nitrates present in the sample to nitrite. The nitrite ions react in an acidic medium with sulfanilic acid to form an intermediate diazonum salt, which couples to chromotropic acid to form a pink coloured product (Hach, 2000). Lastly, the ammonia-nitrogen analysis was determined following the standard method 8038 (0-2.50 mg/L NH_3-N) (Hach, 2000). The Polyvinyl Alcohol Dispersing Agent aids the colour formation in the reaction of Nessler Reagent with ammonium ions. A yellow colour was formed proportional to the ammonia concentrations (Hach, 2000).

3.4 Heavy Metal Analysis

According to the Telliard (1996), the EPA has prescribed Method 1669 for sampling ambient water for trace metals at EPA water quality criteria levels. The sample of the water was collected and transported to the laboratory for analysis. It was important to prevent the outside contamination to the sample at every step of the collection, transportation and analytical process. Before sampling, all the equipment and bottle samples were cleaned by using detergents, mineral acids and reagent water in the laboratory. In the laboratory, the dissolved trace metal concentrations in the water samples were determined for Cd, Cu, Fe, Ni, Pb and Zn using an air-acetylene flame Atomic Absorption Spectrophotometer (AAS) Perkin-Elmer Model AAnalyst 800 since they were within the detection limits (Yap *et al.*, 2011). This study examined or tested only six elements of heavy metals which are nickel, arsenic, lead, manganese, zinc, and copper. Water samples had undergone through a digestion for flame atomic absorption and high level concentrations were done based on Method 3030 E. Nitric Acid Digestion (APHA, AWWA, WEF, 1998) before been analyzed by using Thermo Scientific iCE 3500 Atomic Absorption Spectrometer.

3.5 Statistical Analysis

The statistical analysis of data was determined by using SPSS (Version 20) and Microsoft Excel. All the data recorded had been compared with Marine Water Quality Standard (MWQS) in order to determine the classes for the water quality at Tanjong Bajong coast.

RESULTS

4.0 *In-situ* Water Parameters

The *in-situ* parameters such as temperature, turbidity, salinity, dissolved oxygen, depth, conductivity, pH, and transparency of Tanjung Bajong coast were shown in Figures 2, 3, 4, 5, 6, 7, 8, and 9.

The water temperature at six sampling stations ranged from 29.6 ° C to 35.1 °C (Figure 2). The highest temperature was recorded at Station 6 with 35.1°C, while the lowest temperature was 29.6 °C at Station 1. The measurement of water temperature at Station 1 to 3 was carried out in the morning (9.48 am-11.00 am) while measurement at station 4 to 6 was done in the afternoon (12.00pm to 3.00 pm).

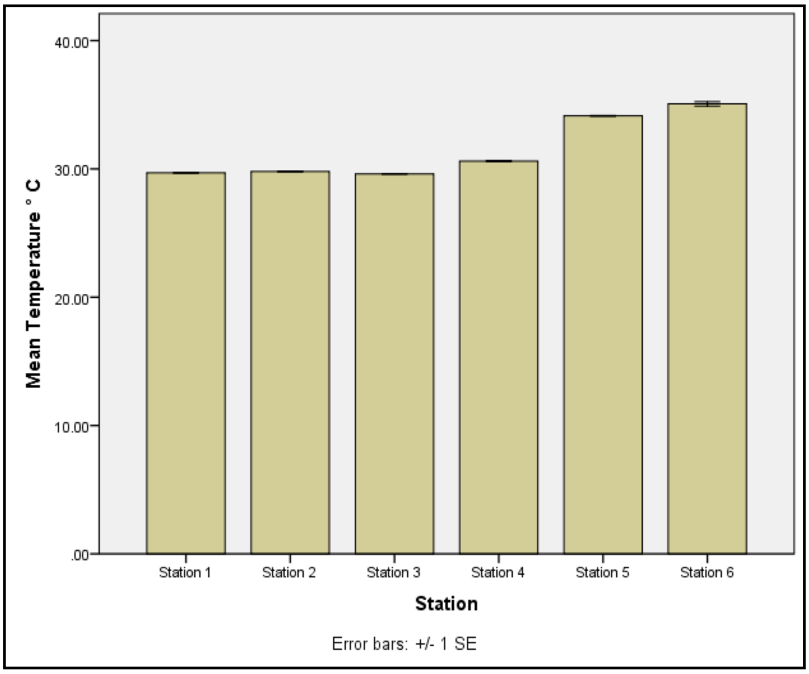

Figure 2: Mean (± SD) value of temperature at six stations

The highest value of turbidity was recorded at Station 2 (295.0 NTU), while the lowest value was at Station 5 (90.0 NTU) (Figure 3). Turbidity was increased from Station 1 to Station 2, then started to decrease from Station 3 until Station 6.

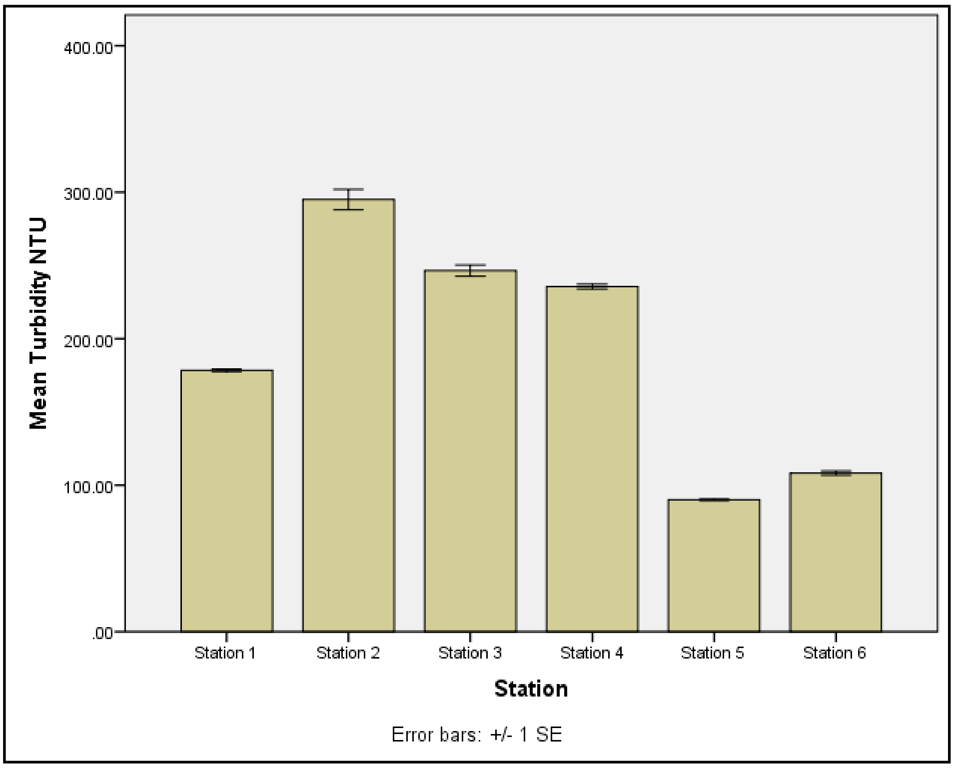

Figure 3: Mean (± SD) value of turbidity at six sampling stations

Salinity ranged from 18.3 PSU to 23.8 PSU (Figure 4). The highest value of salinity was recorded at Station 1 with 23.8 PSU, while the lowest was 18.3 PSU at Station 6. Figure 4 shows the trend for the salinity that decreasing from Station 1 to Station 6. But, salinity at Station 4 was much higher than Station 3. The salinity at all stations was measured during ebb tide.

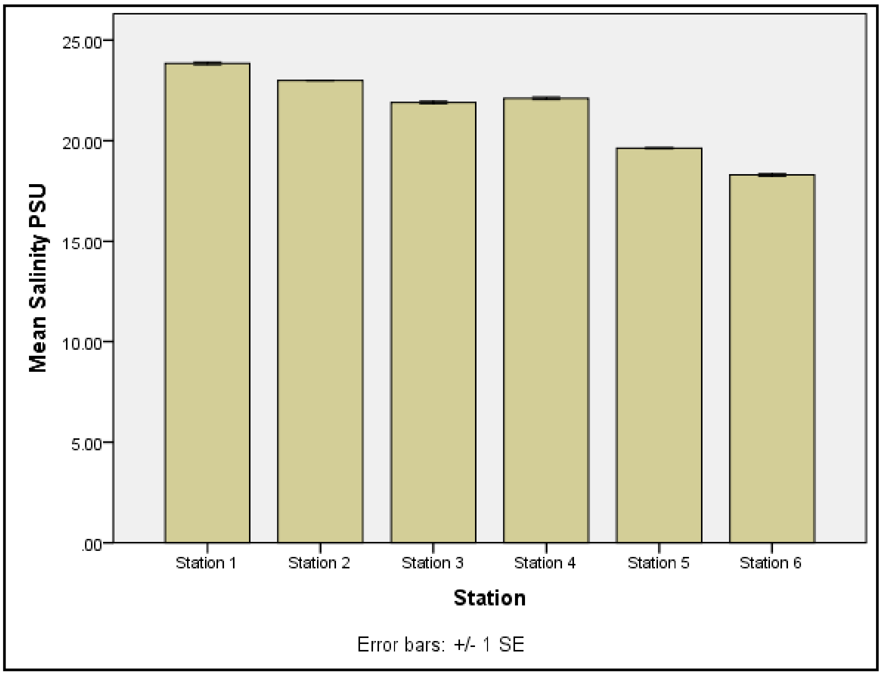

Figure 4: Mean (± SD) value of salinity at six sampling stations

Dissolved oxygen (DO) within six sampling stations ranged from 6.49mg/L to 10.38mg/L (Figure 5). The highest dissolved oxygen recorded was 10.38 mg/L at the Station 4, while, the lowest was recorded at Station 1 with the value 6.49 mg/L. The trends for dissolved oxygen at six sampling stations were increased from Station 1 to 4. However, salinity starts to decrease from Station 4 till Station 6.

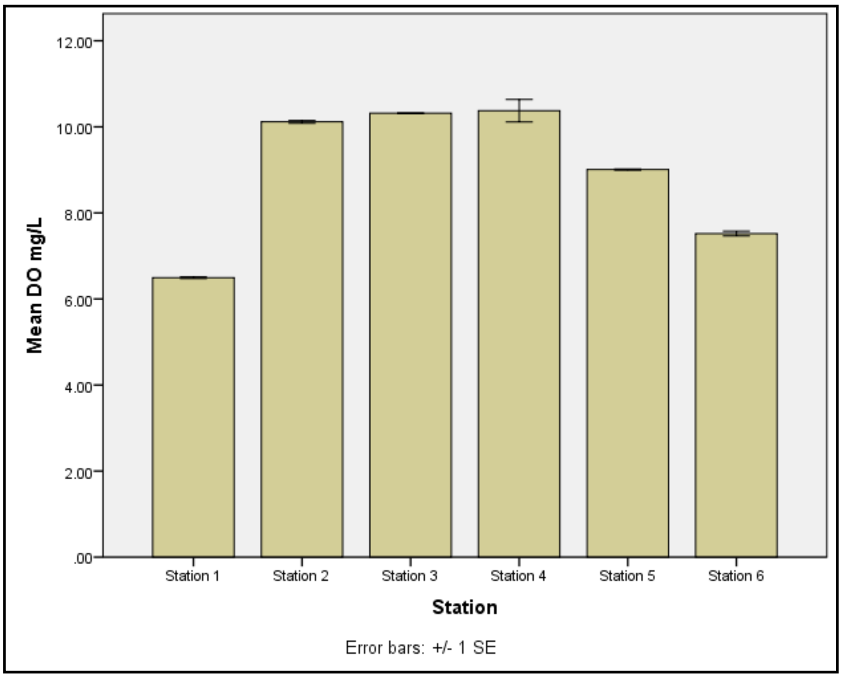

Figure 5: Mean (± SD) value of the dissolved oxygen (DO) at six sampling stations

The highest value for depths recorded for all six sampling stations was 1.4m at Station 4 (Figure 6). The shallowest among six sampling stations was recorded at Station 2 with 0.6m depths. Depths for all six sampling stations ranged from 0.6m to 1.4m (Figure 6).

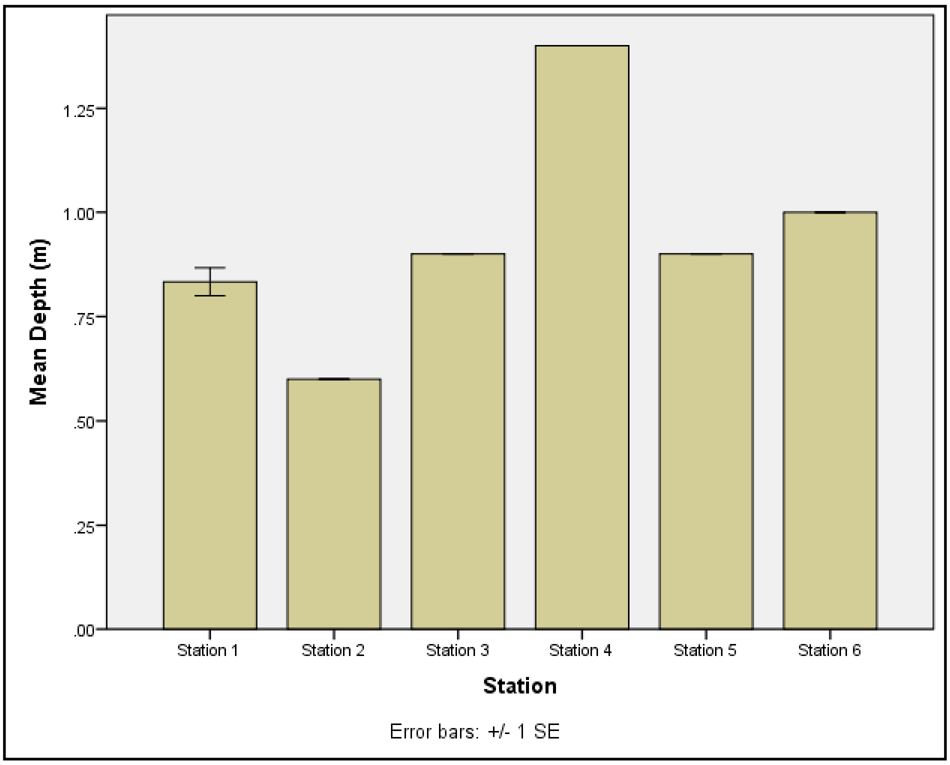

Figure 6: Mean (± SD) value of depth at six sampling stations

Conductivity for six sampling stations ranged from 28.48µS to 34.61µS (Figure 7). The highest conductivity was recorded at Station 1 with 34.61µS, while, the lowest conductivity was at Station 6 with the value 28.48 µS. The trend for conductivity was decreased from Station 1 till Station 6.

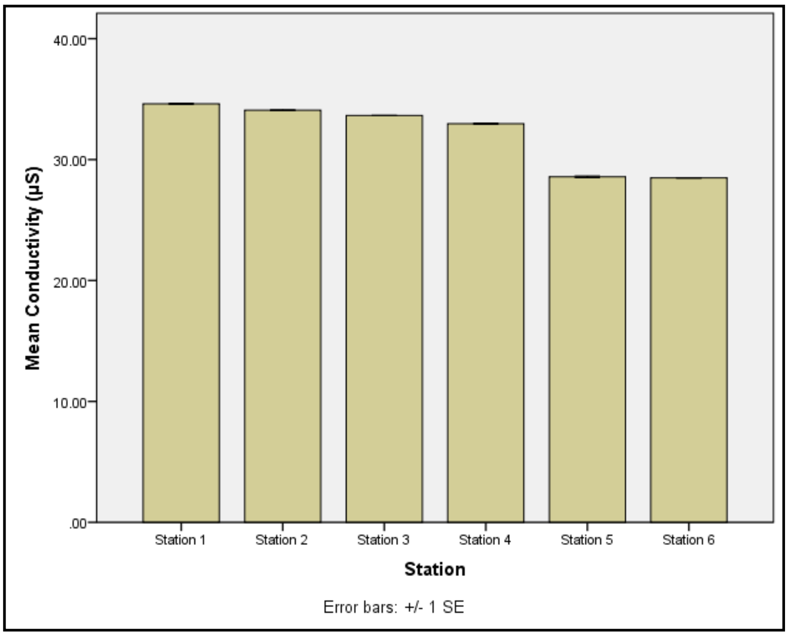

Figure 7: Mean (± SD) value of the conductivity at six sampling station

The pH of six sampling station varied from 7.50 to 7.77 (Figure 8). The lowest pH was recorded at Station 5 (7.50), while the highest pH value was recorded at Station 1 and 2 (7.77). The pH was found in neutral range.

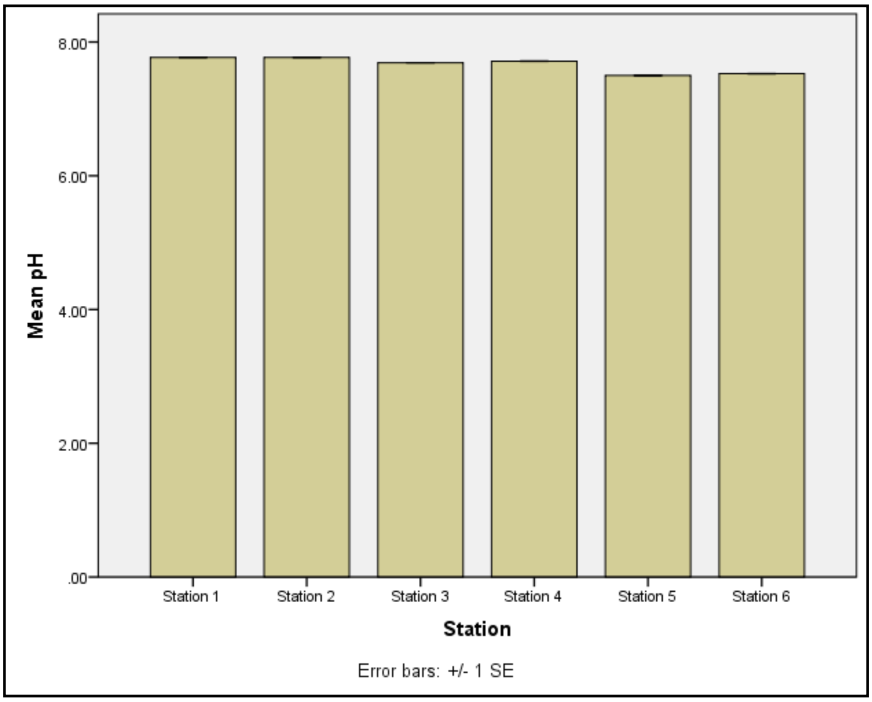

Figure 8: Mean (± SD) value of the pH at six sampling stations

The turbidity recorded for all sampling stations were quite high (Figure 3). Transparency of all sampling stations was not much varied from each other (Figure 9). The transparency values of six sampling stations mostly ranged from 10 to 13mm.

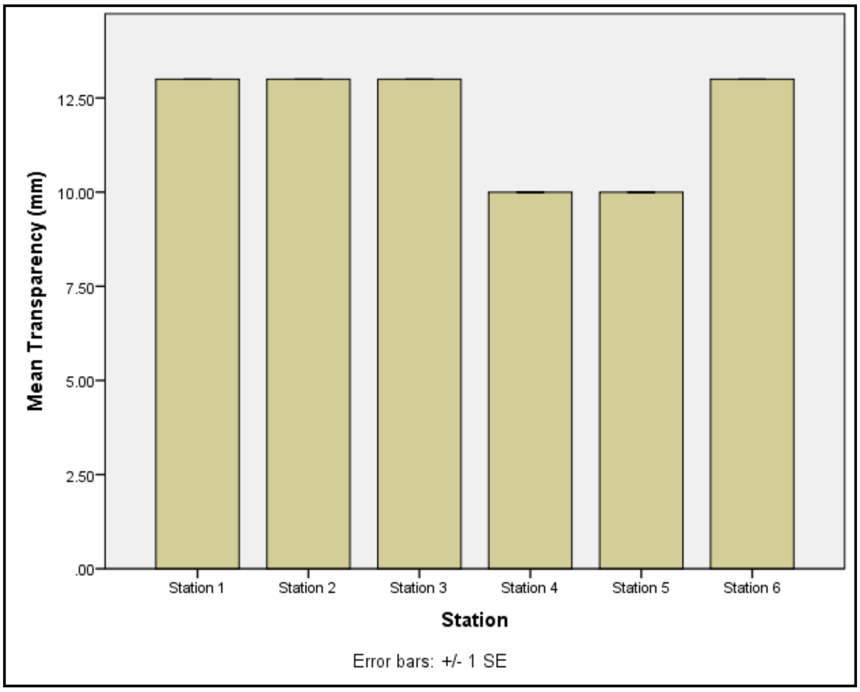

Figure 9: Mean (± SD) value of transparency at six sampling stations

4.1 *Ex-situ* Parameters

Ex-situ parameters consist of biochemical oxygen demand in 5 days (BOD_5), total suspended solid (TSS), chlorophyll *a*, and nutrient analysis (nitrite, nitrate, orthophosphate). The parameters were shown in Figures 10, 11, 12, 13, 14, and 15.

Total suspended solid (TSS) ranged from 247.22 mg/L to 796.89 mg/L (Figure 10). The highest value of total suspended solid was 796.89 mg/L which was recorded at Station 5, while the lowest value of total suspended solid was 247.22 mg/L which was recorded at Station 6.

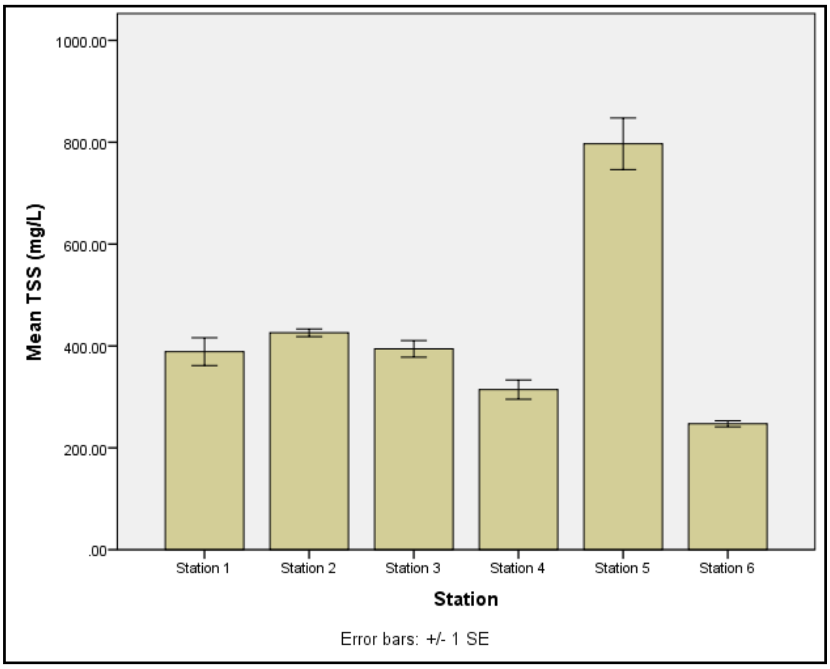

Figure 10: Mean (± SD) value of Total Suspended Solid (TSS) at six sampling stations

Biochemical oxygen demand in five days (BOD_5) varied from 2.73 mg/L to 6.70 mg/L (Figure 11). The highest value for BOD_5 was 6.70 mg/L which was recorded at Station 4. The lowest value for BOD_5 was 2.73 mg/L which was recorded at Station 1. The value of BOD_5 was high at station 2, 3 and 4 started to decrease from Station 5 to Station 6.

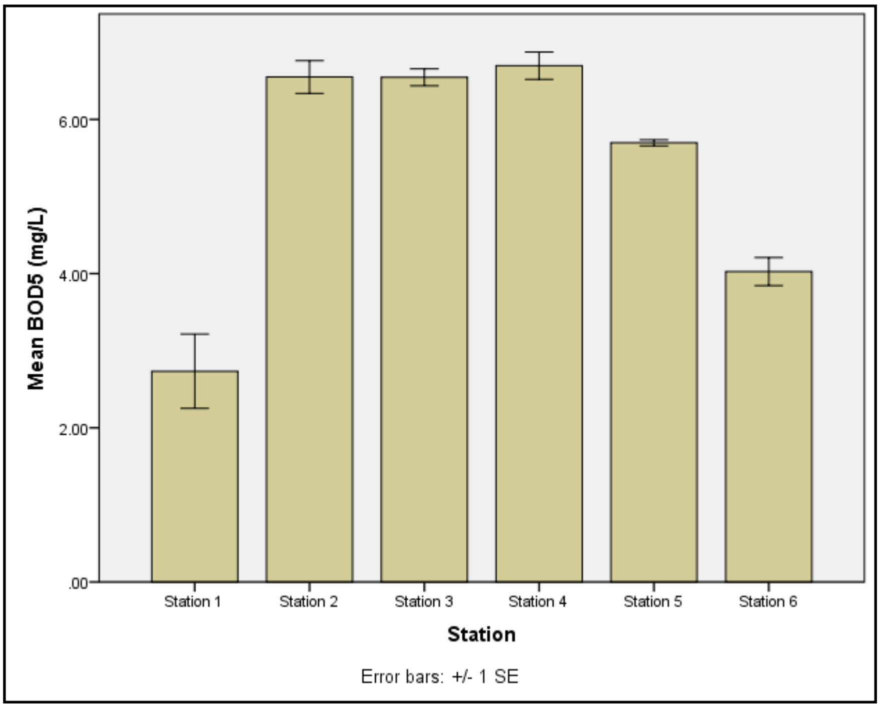

Figure 11: Mean (± SD) value of Biochemical Oxygen Demand in 5 Days (BOD_5) (mg/L) at six sampling stations

Chlorophyll *a* of six sampling stations ranged from 5.07 mg/L to 10.43 mg/L (Figure 12). The highest value of chlorophyll *a* was 10.43 mg/L which was recorded at Station 6. The lowest value of chlorophyll *a* was 5.07 mg/L (Station 4). The chlorophyll *a* fluctuated for all sampling stations.

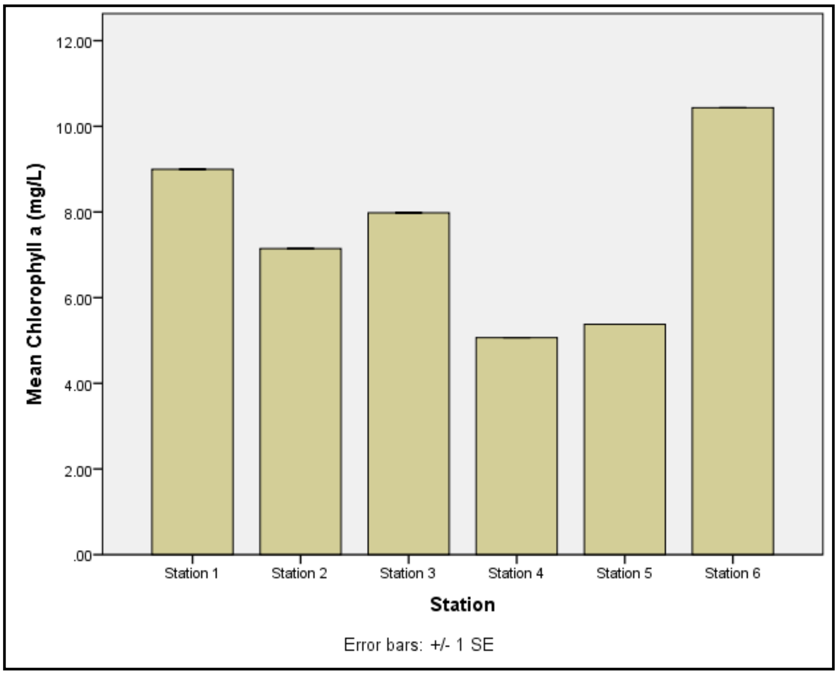

Figure 12: Mean (± SD) value of chlorophyll *a* (mg/L) at six sampling stations

Orthophosphate of six sampling stations ranged from 0.02 mg/L to 0.23 mg/L (Figure 13). The highest value for orthophosphate was 0.23 mg/L which was recorded at Station 1, while the lowest value was 0.02 mg/L which was recorded at Station 4. The value of orthophosphate was decreased from Station 1 to Station 2 and slightly increased at Station 3. The value of orthophosphate was decreased again at Station 4 and became constant at Station 5 and 6.

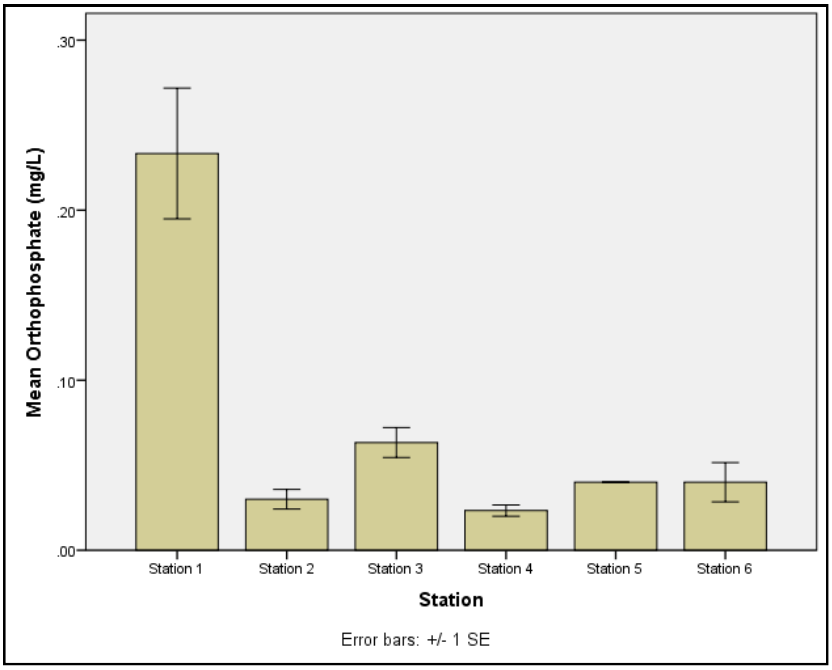

Figure 13: Mean (± SD) value of orthophosphate (mg/L) at six sampling stations

Nitrate varied from 0.03 mg/L to 0.043 mg/L (Figure 14). The highest value of nitrate was recorded at Station 1 (0.043 mg/L). The lowest value of nitrate was found at Station 4 and 6 (0.03 mg/L).

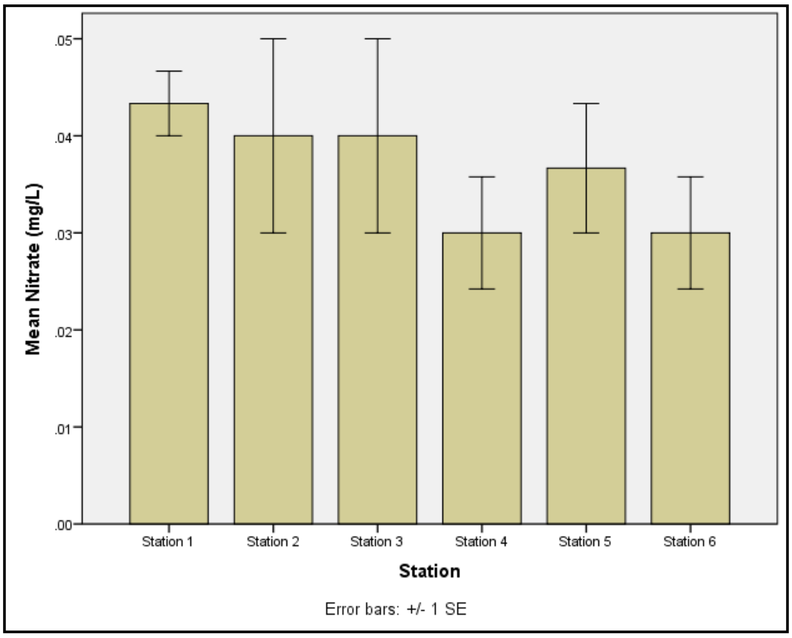

Figure 14: Mean (± SD) value of nitrate (mg/L) at six sampling stations

The highest value of nitrite was recorded at Station 3 (0.016 mg/L), while the lowest value was recorded at Station 2 and 6 (0.013 mg/L). The values fluctuated within all sampling stations (Figure 15).

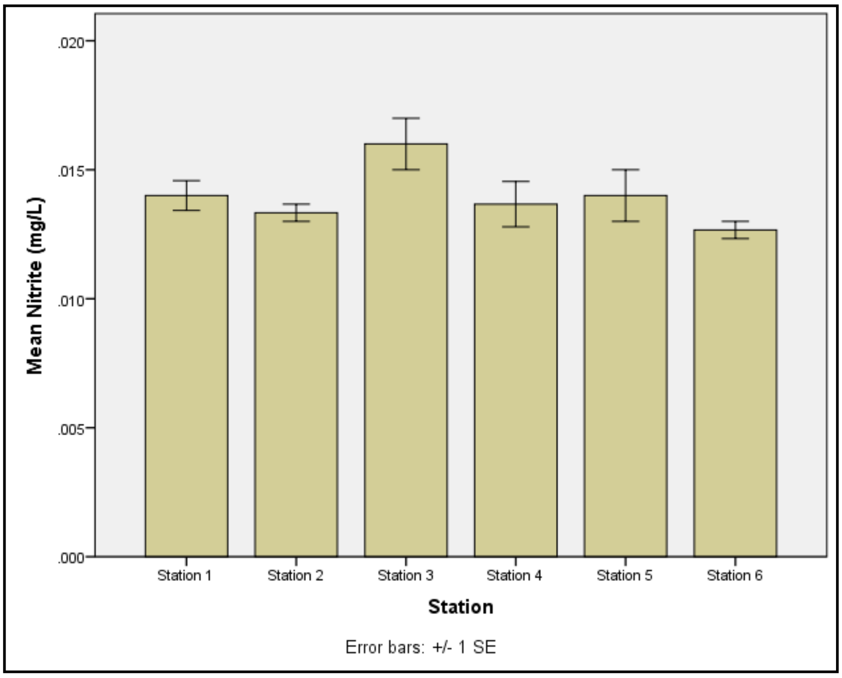

Figure 15: Mean (± SD) value of nitrite (mg/L) at six sampling stations

4.2 Heavy Metals

There were six elements of heavy metals that have been analyzed such as nickel (Ni), arsenic (As), lead (Pb), manganese (Mn), zinc (Zn), and copper (Cu). These six elements were shown in Figures 16 and 17.

Zinc ranged from 0.007 mg/L to 0.037 mg/L (Figure 16). The highest value of zinc was recorded at Station 5 (0.037 mg/L), while the lowest value was recorded at Station 3 (0.007 mg/L). The values were decreased from station 2 to 3 and started to increase from station 4 till 6.

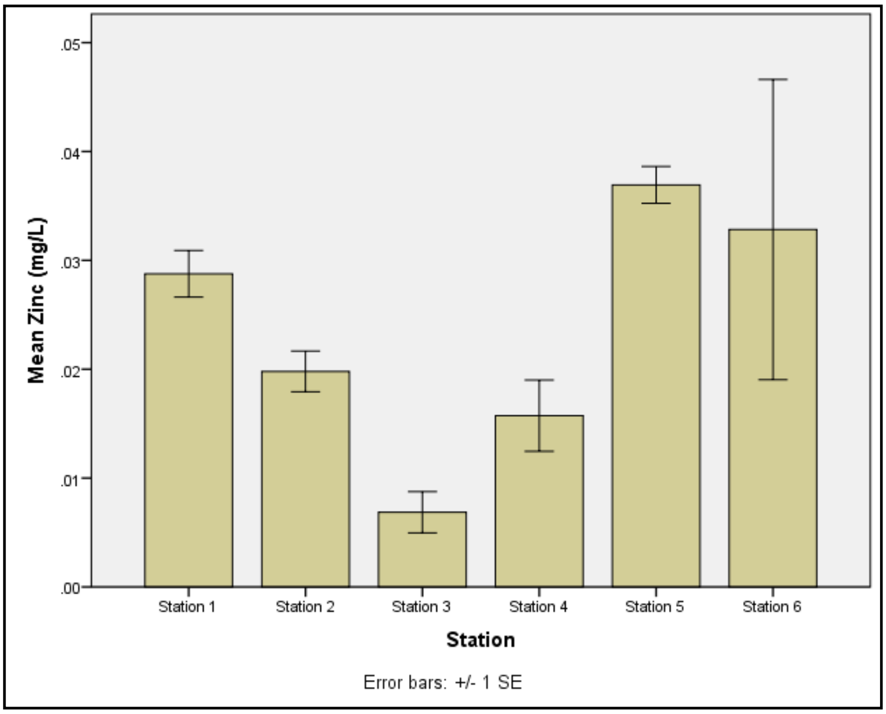

Figure 16: Mean (± SD) value of zinc (mg/L) at six sampling stations

The highest value of manganese was 0.2862 mg/L which was recorded at Station 5 (Figure 20). The lowest value of manganese was 0.0711 mg/L which recorded was at Station 3. The concentrations of manganese in the study area were also low.

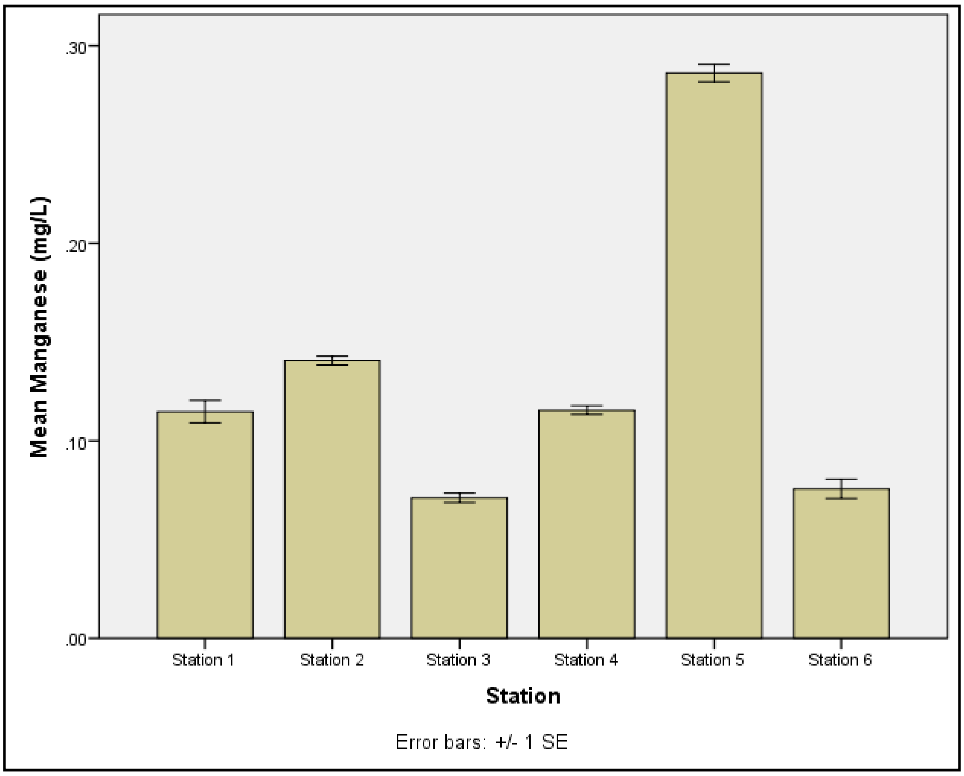

Figure 17: Mean (± SD) value of manganese (mg/L) at six sampling stations

Meanwhile, the abundance of nickel, arsenic, lead, and copper at all sampling stations were under detectable limit. It is because most of the values of nickel, arsenic, lead, and copper were below the value 0.

DISCUSSION

5.0 Water quality parameters

The temperature at Tanjung Bajong which ranged from 29.6 ° C to 35.1 °C can be categorized as warm water. This condition was due to the time of sampling the temperature at all six sampling stations which was at almost noon. The surface of water would be warmer as a result of direct sunlight penetration. Time factor, air temperature and solar radiation are some of the factors affecting the water temperature (Norseila, 2008).

pH is a major environmental factor of aquatic ecosystems at the interface of physico-chemical and biological processes. It is regulated by carbonate equilibrium, both in ocean and in most inland waters, and is impacted by biological processes such as photosynthesis and respiration (Nurhidayah, 2007).The pH value of water depends on types of rocks or soil, carbonate system, temperature and the nature of pollutant discharged (Battarbee, 1986 as cited by Norseila, 2008). The pH value at Tanjung Bajong which ranged from 7.50 to 7.77 can be considered as neutral.

Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity (Yap *et al.*, 2011). Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and microscopic organisms (Lawler, 2004 as cited by Yap *et al*., 2011). For this study, the values of turbidity recorded from six sampling stations were quite high. This could explain the condition of transparency parameter which recorded quite low as the coastal water was very turbid at that time. According to Yap *et al.* (2011), high turbidity and the associated suspended solid concentrations have important ecological impacts, because of light suppression effects. Tanjung Bajong coastal water is a muddy place with mangrove forests can be found along the coastal water which can contribute to the high turbidity within six sampling stations. Low total suspended solid concentration allow sunlight to penetrate sufficiently in water, facilitates the process of photosynthesis which increases its release of oxygen into the water. Low turbidity could enhance visibility in water also sustains the health of the marine ecosystem.

For dissolved oxygen, it ranged from 6.49mg/L to 10.38mg/L. Water is considered 'healthy' when the dissolved oxygen is above 5mg/L (Lau, 2003 as cited by Norseila, 2008). As the value of dissolved oxygen recorded in this study is higher than 5 mg/L, it can be considered that the coastal water was healthy. The depth of sampling stations is less than 1.4 meter, therefore the influences of wave on the dissolved oxygen is also high. This condition can contribute to the higher value in dissolved oxygen. Other than that, photosynthetic activities could also contribute high dissolved oxygen. The major factor controlling dissolved oxygen concentration is biological activity: photosynthesis producing oxygen while respiration and nitrification consume oxygen (although under hypoxic or anoxic conditions denitrification can be a source of oxygen) (Best *et al.*, 2007 as cited by Yap *et al.*, 2011).

Biological oxygen demand in 5 days (BOD_5) is a measure of oxygen used by microorganisms in the oxidation of organic matter within five days. Biological oxygen demand (BOD) is one of essential parameter in order to determine organic pollutant level as consequence of domestic wastes, agricultural waste and anthropogenic inputs (Hoai *et* *al.*, 2006; Hernandez-Romero *et al.*, 2004 as cited by Yap *et al.*, 2011). For this study, BOD_5 ranged from 2.73mg/L to 6.70mg/L. Organic matter may be provided by mangrove forest along the Tanjung Bajong coast as well as decaying of aquatic plantation such as phytoplankton.

Salinity is an ecological factor of considerable importance, influencing the types of organisms that live in a body water (Yap *et al.*, 20011). For this study, the value of salinity was low at all stations. The values fall within the freshwater range. It can be explained as its location was located inward and there are three rivers nearby sampling stations namely Lupar River, Sebuyau River and Sadong River. Therefore, influx of freshwater from those rivers influences the salinity in the study area. Conductivity is a presence of charged ionic species in solution which enables water to conduct an electric current, electrical conductivity (EC) or conductance and is directly related to total dissolved salt concentration such as chloride, nitrate, sulfate, phosphate, magnesium, calcium, iron, and aluminium in the water. Small daily fluctuations of salinity and conductivity as a result of evaporation during the day and condensation and groundwater recharge at night.

Chlorophyll *a* concentration is an indicator of phytoplankton abundance and biomass in coastal and estuarine waters. It absorbs sunlight during photosynthesis process and converts it into glucose. Chlorophyll *a* is an important indicator for the status of water quality in a marine ecosystem to identify the inputs of nutrients and the presence of photosynthetic plankton. It's concentration often higher after rainfall, particularly if rain has flushed the nutrients into water.

Nitrates are used primarily to make fertilizer. These compounds are also used in various chemical production and separation processes. Nitrites are manufactured mainly for use as a food preservative. Nitrates are naturally present in soil, water, and food. Nitrites are produced when microorganisms convert the nitrate or the ammonium ion. Nitrate and nitrite compounds are very soluble in water and have a high potential for entering surface water when it rains. For this study, the concentration of nitrate and nitrite not exceed the standard that been provided in Malaysia Marine Water Quality Criteria and Standard (MWQS).

5.1 Heavy metals

Some heavy metals, such as Zn, Cu, Mn, and Fe, are essential for aquatic organisms, but show toxic effects when organisms are exposed to higher abnormal concentrations (Massoud, 2003). For this study, there are several heavy metals under detectable limit such as nickel, arsenic, lead, and copper. This condition shows that the concentration of nickel, arsenic, lead, and copper are low. The low concentration of copper can be explained possibly as a result of dilution by water from three rivers nearby the sampling stations. For nickel, it usually used as a propeller shafts in boats. As most of the people who lived nearby Tanjung Bajong are mostly fishermen which is usually used boats as their transportation. As for arsenic, it can be found naturally on earth in small concentrations. Due to human activities, mainly through mining and melting, naturally immobile arsenics have also mobilized and can now be found on many more places than where they existed naturally. There is a quarry can be found along Tanjung Bajong. Quarry can be one of the sources that contribute to the concentration of arsenic in water body.

5.2 Malaysia Marine Water Quality Criteria and Standard (MWQS)

Most of the parameters fit into the classes E of the standard that stated in Malaysia Marine Water Quality Criteria and Standard (MWQS) which could explain the environmental feature of Tanjung Bajong that consist of mangrove estuarine (refer to Table 1). As mentioned ealier, there are mangrove trees along the Tanjong Bajong coastal area. Therefore, Tanjung Bajong coast is categorized under class E in Malaysia Marine Water Quality Criteria and Standard.

CONCLUSION

This study had been conducted to determine the physico- chemical parameters and water quality status at Tanjung Bajong coast. Based on Malaysia Marine Water Quality Criteria and Standard (MWQS), Tanjung Bajong coast is categorized under class E which is fit for mangrove estuarine. Other than that, there is still lack of information regarding coastal water in Tanjung Bajong and further study have to be carried out for better management in that area. It is because most of people from nearby villages depend on water resources as their socio-economic activities such as fishing activities. Furthermore, better data collection could make a better management for sustainable coastal water resources.

REFERENCES

Alan P.T & Harold V.T (2008). *Essentials of Oceanography*. Ninth Edition. Pearson Education Inc. and Prentice Hall.(pp 140, 332)

Department of Environment (2011). Malaysia Marine Water Quality Criteria and Standard. Retrieved 25 April, 2012 from http:// www.doe.gov.my

EPA (2001). *Parameters of Water Quality*: Interpretation and Standards. Environmental Protection Agency, Ireland. pp 28.

Ling T.Y, Ng S.C, Lee N. & Buda D. (2009). Oxygen Demand of the Sediment from the Semariang Batu River, Malaysia. *World Applied Sciences Journal 7(40),* 440-447.

Massoud A.H.S. (2003). Impact of Diffuse Pollution on the Socio-economic Development Opportunities in the Coastal Nile Delta Lakes. *Diffuse Pollution Dublin Conference 2003.*

Njogu P. M., Keriko J. M., Wanjau R. N. & Kitetu J. J. (2011). Distribution of Heavy Metals in Various Lake Matrices; Water, Soil, Fish and Sediments: A Case Study of the Lake Naivasha Basin, Kenya. *JAGST Vol. 13(1) 2011.*

Norseila N. (2008). Benthic Diatoms of Sungai Kuap, Sarawak. Final Year Project Report. Faculty of Resource Science and Technology. Universiti Malaysia Sarawak. (pp 45-46)

Nurhidayah H. (2007). Assessment on Water Quality and Biodiversity within Sungai Batu Pahat. Msc Thesis. Faculty of Civil Engineering. Universiti Teknologi Malaysia. (pp 58-67)

Öztürk M., Özözen G., Minareci O., & Minareci E. (2009). Determination of Heavy Metals in Fish, Water and Sediments of Avsar Dam Lake in Turkey. *Iran. J. Environ. Health. Sci. Eng., 2009,* Vol. 6, No. 2, pp. 73-80.

Raman B., Bouwmeesteer R. & Mohan S. (2009). Fuzzy Logic Water Quality Index and Importance of Water Quality Parameters. *Air ,Soil and Water Research* 2009:2 (pp.51-59)

Shahrizaila A.(1993).Coastal Developments in Malaysia Scope, Issues and Challenges. Department of Irrigation and Drainage Malaysia.

Sungai Bajong, Sarawak, Malaysia (2011). Retrieved 25 March, 2011 from I:/ Sungai Bajong-Sungai Bajong, Sarawak, Malaysia, Asia.mht.

Telliard W.A. (1996).Method 1669; Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels (July, 1996): US Environmental Protection Agency, Office of Water, Engineering and Analysis Divison (4303), 401 M Streets S.W., Washington, D.C. 20460

Yap C.K, Chee M.W., Shamarina,Edward F.B, Chew W. & Tan S.G. (2011). Assessment of Surface Water Quality in the Malaysian Coastal Waters by Using Multivariate Analyses. *Sains Malaysiana* 40(10)(2011): 1053-1064