WATER QUALITY AT TANJUNG BAJONG COAST, SEBUYAU, SARAWAK

Noziena Mura Noel

Bachelor of Science with Honours
(Aquatic Resource Science and Management)
2012
ACKNOWLEDGEMENT

First and foremost, I would like to thank God for His blessing in enabling me to complete this final year project. I would like to express my gratitude and appreciation to my supervisor, Prof. Shabdin Mohd Long for his guidance and encouragement throughout the completion of this final year project. Not to forget, to all Aquatic Science Programme's laboratory assistants, Mr. Zaidi Ibrahim, Mr. Mohamad Norazlan, Mr. Haris Norman, Mr. Nazri Latip, Mr. Zulkifli Ahmad, and Mr. Richard Toh for helping me during field trip and laboratory works.

Finally, I would like to express my warmest thanks to my family for the encouragement, understanding and financial support for me to accomplish this final year project. Last but not least, I would like to give special thanks to my friends Faddrine Holt, Nurul Azliza, Norbaiaah, who were always been there for me for giving their helpful hands and warmest encouragement to accomplish this project. Accomplishment of this final year project won’t be enjoyable and memorable without them.
Table of Contents

Acknowledgement ................................................................. I
Table of Contents ................................................................. II
List of Abbreviations ............................................................... IV
List of Tables and Figures ....................................................... V
Abstract ................................................................................ 1
Introduction ........................................................................... 2

Literature Review ................................................................ 4
  Water Quality Parameter ....................................................... 4
  Salinity ............................................................................. 5
  Temperature ....................................................................... 5
  Total Suspended Solids ......................................................... 5
  Dissolved Oxygen ............................................................... 6
  Conductivity ....................................................................... 7
  Heavy Metal ....................................................................... 7
  Marine Water Quality Criteria and Standard (MWQS) ............. 9

Materials and Methods .......................................................... 10
  Study Site ......................................................................... 10
  Environmental Parameters ................................................... 11
  Laboratory Analysis ........................................................... 12
    Total Suspended Solids ...................................................... 12
    BOD$_5$ ........................................................................ 13
    Chlorophyll –a ................................................................. 14
    Nutrient Analysis ............................................................. 15
    Heavy Metals ................................................................. 16
  Statistical Analysis ............................................................. 17

Results .................................................................................. 18
  In-situ Parameters ............................................................. 18
  Ex-situ Parameters ............................................................. 26
  Heavy Metals ...................................................................... 32

Discussion ............................................................................ 35
  Water Quality Parameters .................................................. 35
  Heavy Metals ..................................................................... 38
  Marine Water Quality Criteria and Standard (MWQS) .......... 39
### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAS</td>
<td>Atomic Absorption Spectrophotometer</td>
</tr>
<tr>
<td>APHA</td>
<td>American Public Health Association</td>
</tr>
<tr>
<td>BOD</td>
<td>Biochemical Oxygen Demand</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>DO</td>
<td>Dissolved Oxygen</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Environment, Malaysia</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>H₂O</td>
<td>Water</td>
</tr>
<tr>
<td>MWQS</td>
<td>Marine Water Quality Criteria and Standards</td>
</tr>
<tr>
<td>NTU</td>
<td>Nephelometric Turbidity Unit</td>
</tr>
<tr>
<td>PSU</td>
<td>Practical Salinity Unit</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package Social Science</td>
</tr>
<tr>
<td>TSS</td>
<td>Total Suspended Solids</td>
</tr>
</tbody>
</table>
Lists of Tables

Table 1: Marine Water Quality Criteria and Standards
Table 2: Sampling stations and the GPS coordinate

Lists of Figures

Figure 1: Sampling stations established in Tanjung Bajong coast
Figure 2: Mean (± SD) value of temperature at six stations
Figure 3: Mean (± SD) value of turbidity at six sampling stations
Figure 4: Mean (± SD) value of salinity at six sampling stations
Figure 5: Mean (± SD) value of the dissolved oxygen (DO) at six sampling stations
Figure 6: Mean (± SD) value of depth at six sampling stations
Figure 7: Mean (± SD) value of the conductivity at six sampling station
Figure 8: Mean (± SD) value of the pH at six sampling stations
Figure 9: Mean (± SD) value of transparency at six sampling stations
Figure 10: Mean (± SD) value of Total Suspended Solid (TSS) at six sampling stations
Figure 11: Mean (± SD) value of Biological Oxygen Demand in 5 Days (BOD₅) at six sampling stations
Figure 12: Mean (± SD) value of chlorophyll a at six sampling stations
Figure 13: Mean (± SD) value of orthophosphate at six sampling stations
Figure 14: Mean (± SD) value of nitrate at six sampling stations
Figure 15: Mean (± SD) value of nitrite at six sampling stations
Figure 16: Mean (± SD) value of zinc at six sampling stations
Figure 17: Mean (± SD) value of manganese at six sampling stations
Water Quality at Tanjung Bajong coast, Sebuyau, Sarawak

Noziena Mura Noel

Aquatic Resource Science and Management
Faculty of Resource Science and Technology
Universiti Malaysia Sarawak

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), BOD₅, 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 - 10.38 mg/L for DO, 0.6 - 1.4 m for depth, 28.48 - 34.61 μS for conductivity, 7.50 - 7.77 for pH, 10 - 13 mm for transparency, 247.22 - 796.89 mg/L for TSS, 2.73 - 6.70 mg/L for BOD₅, 5.07 - 10.43 mg/L for chlorophyll a, 0.02 - 0.23 mg/L for orthophosphate, 0.03 - 0.043 mg/L for nitrate, 0.013 - 0.016 mg/L for nitrite. The ranges of heavy metals (mg/L) are 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 ialah jumlah ampiran pepejal (TSS), BOD₅, 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 - 10.38 mg/L (DO), 0.6 - 1.4 m (kedalaman), 28.48 - 34.61 μS (konduktiviti), 7.50 - 7.77 (pH), 10 - 13 mm (kejernihan), 247.22 - 796.89 mg/L (TSS), 2.73 - 6.70 mg/L (BOD₅), 5.07 - 10.43 mg/L (klorofil a), 0.02 - 0.23 mg/L (ortofosfat), 0.03 - 0.043 mg/L (nitrat), 0.013 - 0.016 mg/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.p.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 used 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)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CLASS 1</th>
<th>CLASS 2</th>
<th>CLASS 3</th>
<th>CLASS E</th>
</tr>
</thead>
<tbody>
<tr>
<td>BENEFICIAL USES</td>
<td>Preservation, Marine Protected areas, Marine Parks</td>
<td>Marine Fisheries, Coral Reefs, Parks</td>
<td>Life, Marine Recreation and Mariculture</td>
<td>Mangroves Estuarine &amp; River-mouth Water</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>≤ 2°C increase over maximum ambient</td>
<td>≤ 2°C increase over maximum ambient</td>
<td>≤ 2°C increase over maximum ambient</td>
<td>≤ 2°C increase over maximum ambient</td>
</tr>
<tr>
<td>Dissolved oxygen (mg/L)</td>
<td>&gt;80% saturation</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total suspended solid (mg/L)</td>
<td>25 mg/L or ≤ 10% increase in seasonal average, whichever is lower</td>
<td>50 mg/L (25 mg/L) or ≤ 10% increase in seasonal average, whichever is lower</td>
<td>100 mg/L or ≤ 10% increase in seasonal average, whichever is lower</td>
<td>100 mg/L or ≤ 30% increase in seasonal average, whichever is lower</td>
</tr>
<tr>
<td>Oil and grease (mg/L)</td>
<td>0.01</td>
<td>0.14</td>
<td>5</td>
<td>0.14</td>
</tr>
<tr>
<td>Mercury* (µg/L)</td>
<td>0.04</td>
<td>0.16 (0.04)</td>
<td>50</td>
<td>0.5</td>
</tr>
<tr>
<td>Cadmium (µg/L)</td>
<td>0.5</td>
<td>2 (3)</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Chromium (VI) (µg/L)</td>
<td>5</td>
<td>10</td>
<td>48</td>
<td>10</td>
</tr>
<tr>
<td>Copper (µg/L)</td>
<td>1.3</td>
<td>2.9</td>
<td>10</td>
<td>2.9</td>
</tr>
<tr>
<td>Arsenic (III)*</td>
<td>3</td>
<td>20 (3)</td>
<td>50</td>
<td>20 (3)</td>
</tr>
<tr>
<td>Substance</td>
<td>Unit (µg/L)</td>
<td>Range (µg/L)</td>
<td>Value (µg/L)</td>
<td>Range (µg/L)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Lead (µg/L)</td>
<td></td>
<td>4.4 - 8.5</td>
<td>50 - 8.5</td>
<td></td>
</tr>
<tr>
<td>Zinc (µg/L)</td>
<td></td>
<td>15 - 50</td>
<td>100 - 50</td>
<td></td>
</tr>
<tr>
<td>Cyanide (µg/L)</td>
<td></td>
<td>2 - 7</td>
<td>20 - 7</td>
<td></td>
</tr>
<tr>
<td>Ammonia (unionized) (µg/L)</td>
<td></td>
<td>35 - 70</td>
<td>320 - 70</td>
<td></td>
</tr>
<tr>
<td>Nitrite (NO₂) (µg/L)</td>
<td></td>
<td>10 - 55</td>
<td>1,000 - 55</td>
<td></td>
</tr>
<tr>
<td>Nitrate (NO₃) (µg/L)</td>
<td></td>
<td>10 - 60</td>
<td>1,000 - 60</td>
<td></td>
</tr>
<tr>
<td>Phosphate (µg/L)</td>
<td></td>
<td>5 - 75</td>
<td>670 - 75</td>
<td></td>
</tr>
<tr>
<td>Phenol (µg/L)</td>
<td></td>
<td>1 - 10</td>
<td>100 - 10</td>
<td></td>
</tr>
<tr>
<td>Tributyltin (TBT) (µg/L)</td>
<td></td>
<td>0.001 - 0.01</td>
<td>0.05 - 0.01</td>
<td></td>
</tr>
<tr>
<td>Faecal coliform (Human health protection for seafood consumption) - most Probable Number (MPN)</td>
<td></td>
<td>70 faecal coliform 100mL⁻¹</td>
<td>100 faecal coliform 100mL⁻¹</td>
<td>200 faecal coliform 100mL⁻¹</td>
</tr>
<tr>
<td>Polycyclic Aromatic Hydrocarbon (PAHs) ng/g</td>
<td></td>
<td>100</td>
<td>200</td>
<td>1000</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Stations</th>
<th>GPS reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station 1</td>
<td>N 01° 34.989' E 110° 48.134'</td>
</tr>
<tr>
<td>Station 2</td>
<td>N 01°34.900' E 110°48.457'</td>
</tr>
<tr>
<td>Station 3</td>
<td>N 01°34.685' E 110°48.861'</td>
</tr>
<tr>
<td>Station 4</td>
<td>N 01°34.522' E 110°49.165'</td>
</tr>
<tr>
<td>Station 5</td>
<td>N 01°33.427' E 110°50.693'</td>
</tr>
<tr>
<td>Station 6</td>
<td>N 01°32.308 E 110°52.333'</td>
</tr>
</tbody>
</table>
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), \( \text{BOD}_5 \), chlorophyll \( \alpha \), 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\textsubscript{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:
\[ \text{BOD}_5 (\text{mg/L}) = D_1 - D_5 \]

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:

\[
\text{Chlorophyl } a = 11.85E_{664} \times 1.54E_{647} \times 0.08E_{630} \\
\text{Chlorophyl } b = 21.03E_{647} \times 5.43E_{664} \times 2.66E_{630} \\
\text{Chlorophyl } c = 24.52E_{630} \times 1.67E_{664} \times 7.60E_{647}
\]

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

\[
\text{Chl a (mg/m}^3\) = C_x \times v / V (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 \( \text{PO}_3^{2-} \)). 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 NO₃-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 diazonium 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 NH₃-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](image)