# SEAWATER PROPERTIES IN BRUNEI BAY, SABAH

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DISERTASI INI DIKEMUKAKAN UNTUK MEMENUHI SEBAHAGIAN DARIPADA SYARAT MEMPEROLEHI IJAZAH SARJANA MUDA SAINS DENGAN KEPUJIAN



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## ABSTRACT

This study was carried out at Brunei Bay in 13th and 14th December 2005 and 22nd and 23rd August 2006. It was aimed at investigating the fluctuations of seawater properties (salinity, temperature, dissolved oxygen and pH) in the bay during two monsoon seasons, the Northeast Monsoon and the Southwest Monsoon. These parameters were measured using Hydrolab at a 15 randomly oceanographic stations at the bay. The salinity was less than 29.8 ‰ during the Northeast Monsoon. It increased during the Southwest Monsoon highest salinity recorded was 30.44‰.Strong currents from open sea supplied high saline water and formed strong stratification during the Northeast Monsoon. Sea surface temperature increased due to seasonal effect. The temperature ranged between 29.94 °C– 30.74 °C during the Southwest Monsoon and lower seawater temperature during Northeast Monsoon with range between 26.7 °C - 28.8 °C. DO concentrations range between 2 mg/L – 6.5 mg/L during the NEM, compared to DO concentration during the SWM which was more uniformed with 4.59 mg/L – 5.89 mg/L at 3 m depth and 5.03 mg/L – 5.82 mg/L at 1 m depth. During the NEM, pH was less than 8.8, while during the Southwest Monsoon pH scattered uniformed with lowest pH reading was 7.75 and highest pH reading was 7.86.

## ABSTRAK

Kajian ini telah dijalankan di Teluk Brunei pada 13 dan 14 Disember 2005 dan 22 dan 23 Ogos 2006. Ia bertujuan untuk mengkaji perubahan parameter air laut (saliniti, pH , suhu air laut, dan oksigen terlarut) di kawasan persekitaran teluk semasa dua musim monsun, Monsun Barat Daya dan Monsun Timur Laut. Parameter-parameter ini diukur menggunakan Hydrolab di 15 stesen merangkumi kawasan teluk. Saliniti kurang daripada 29.8 ‰ dicatatkan semasa Monsun Timur Laut. Ia semakin meningkat semasa monsoon Barat Daya dengan saliniti yang dicatatkan adalah 30.44 ‰. Arus kuat daripada laut lepas membekalkan air yang mempunyai kandungan saliniti yang tinggi dan membentuk stratifikasi semasa Monsun Timur Laut. Suhu air laut dipermukaan meningkat disebabkan perubahan musim. Suhu dengan had diantara 29.94 °C– 30.74 °C semasa Monsun Barat Daya dan suhu air laut yang lebih rendah dapat dilihat semasa Monsun Timur Laut dengan had diantara 26.7 °C - 28.8 °C. Kepekatan oksigen terlarut dengan had diantara 2 mg/L – 6.5 mg/L semasa Monsun Timur Laut, berbanding dengan Monsun Barat Daya yang taburannya lebih sekata dengan 4.59 mg/L – 5.89 mg/L pada kedalaman 3 m dan 5.03 mg/L – 5.82 mg/L pada kedalaman 1 m. Semasa Monsun Timur Utara, pH adalah kurang daripada 8.8, dan semasa Monsun Barat Daya pH tertabur secara sekata dengan bacaan pH terendah ialah 7.75 dan bacaan pH tertinggi ialah 7.86.

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| | |
|---|---|
| SWM | South West Monsoon |
| NEM | North East Monsoon |
| mg | milligram |
| m | metre |
| ‰ | part per thousand |
| °C | degree Celsius |
| g/cc | gram per cubic centimetres |
| GPS | Global Positioning System |
| $CO_2$ | Carbon dioxide |
| $O_2$ | Oxygen |
| % | percent |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Seawater properties are the characteristics of seawater which consist of pressure, temperature, hydrostatic pressure, salinity, transparency, conductivity, density, dissolved gases, turbidity, acid-based balance, light and sound. Seawater properties are important for marine life. Marine organisms depend on the physiochemical characteristics for life support. Seawater properties that are most commonly measured are salinity, pH, temperature and dissolved oxygen (DO).

Physio-chemical characteristics of seawater are a direct consequence of the atomic structure of water. The physical nature of the sea is determined largely by the physical properties of seawater. Temperature and salinity directly affect the density, buoyancy and stability of seawater and, consequently the emotion of water in the ocean basins. the physical properties of seawater also strongly influence the behaviour of heat and light in the ocean, thereby controlling thermal and radiant energy in that area. Each seawater properties need to be examined in detail because of their important role in many sea processes such as water circulation (Basu, 2003).

Seawater properties are important for management and further development at the place. Parameters such as salinity, pH, DO and temperature are important for the management options, which promote the optimal use of resources and mitigation some important problem in estuarine system and associated coastal areas. From the measurement of the seawater properties, we can determine the state of water, whether it is being polluted or not.

Seawater properties in an area can be altered by many factors; this includes natural occurrences and anthropogenic factors. Climate change and weather conditions are likely to have considerable direct impacts on most aquatic ecosystem seawater properties. Aspects of climate like temperature and precipitation plays a big role in the change of seawater properties in an area. Weather conditions whereby daily variations of cloud density and wind conditions are involved, directly impact the seawater properties in an area.

Monsoon also has a profound effect on seawater properties. Monsoon which is a wind pattern of wind circulation that changes with the season, affects the water properties such as salinity that is being affected much by monsoons. The Southwest monsoon (SWM) that occurs during May and September is characterized to be calm and dry. The Northeast monsoon (NEM) is characterized by strong winds and heavy rainfall occurred between November and February. The effects of monsoon depend on the area. South East Asia waters are mainly controlled by these two monsoons (Wrytki, 1961). During NEM, it may increase precipitation rate and runoff. It will intensify stresses on estuaries by intensifying the transport of nutrients and contaminations to coastal ecosystems. Coastal erosion leads to losses in organic materials that build beaches and coastlines.

Seawater properties are also affected by anthropogenic activities. Some land management practices including urbanization, farming, forestry, and industrialization have contributed to increase flow of sedimentation and thus, affecting aquatic marine resources. Demand on land space and associated resources have caused the removal important stabilizing vegetation and riparian buffers, altered wetland and increased the amounts of impenetrable surfaces covering the land. As a result of these activities, sediment runoff into estuaries and other coastal areas has increased and is adversely affecting the biodiversity and ecosystem in a number of ways including; changing the physical structure of habitats and endangering those species requiring specific depth, light and water velocity conditions through increased deposition. For example, it will reduce light penetration to seagrass bed, corals, and other communities dependent on the productivity of photosynthesis living on the seafloor.

Sediment runoff also carries pollutants such as heavy metals, organic pollutants and nutrient. Sedimentation interferes with the respiration of species that rely on gills to breathe and damaging delicate organisms such as corals. Sedimentation also covering important spawning habitats of fish and other organism, and smother bottom-dwelling organisms and affect filter feeding species.

Changes in seawater properties can lead to direct effects to the environment and the organisms involved. Environmental factors such as abnormal temperatures or salinities, low DO, may contribute to an increase in the prevalence of pathogen in organisms. Number of factors has caused mass mortalities for marine organisms, such as storms, extreme temperature, salinity changes, and oxygen depletion (Sindermann, 1996). Higher salinity caused by increased by increased evaporation, greater levels of tidal inundation, tidal flooding and shoreline erosion. Higher salinity will alter the composition of ecosystem affecting both the plants and animals living in these habitats. It will mostly threat to stenohaline organism and plants.

Seawater temperature variation changes the sea currents and productivity of organisms. This effect the distribution, abundance and productivity of marine populations, with unpredictable consequences to marine ecosystems and fisheries. Rising of sea temperature further effect the distribution and survival of particular marine resources. In addition to cause a warming effect, increased concentrations of atmospheric carbon dioxide ($CO_2$) are known increases rates of photosynthesis in many plants, as well as improving water use efficiency; it may increase growth rates in some natural and agricultural communities. Increase in $CO_2$ levels could trigger abrupt changes in thermohaline circulation driven by differences in the density of water, controlled by the effects of temperature and salinity. It may result in massive and severe consequences for the oceans and for global climate.

## 1.2 Objectives

The objectives of this study are:

1. To determine the in-situ seawater properties which consist of salinity (‰), DO (mg/L), pH, and temperature (°C) in Brunei Bay.
2. To compare the changes of seawater properties during $13^{th}$ and $14^{th}$ December 2005 and $22^{nd}$ and $23^{rd}$ August 2006.

## 1.3 Significance of Study

The significance of this study is for further management of Brunei Bay. Seawater properties play an important role for management options which promote the optimal use of resource and alleviation of some important problems in estuarine system and associated coastal areas. Parameters such as salinity, pH, DO and temperature influence growth and distribution of corals, mangrove and invertebrates that inhabit the marine environment. Therefore, studying seawater properties in this area will aid in inhabit rehabilitation efforts.

Some species of fish are known to migrate with or within the surface layer due to changes of the water characteristics (Bond, 1978). Thus, the knowledge of seawater properties will help in the fisheries management sector. For example, with the exact data of seawater profile, the existence of fish population in a specific water column can be predicted. Significant changes in survival rates of planktonic organisms which drift in the surface temperature are also known to cause the collapse of fisheries industries (Philander, 1989). Thus, data on the seawater properties will assist in the understanding of the yield and factors contributing to the current fisheries condition.

The study of seawater properties will facilitate pollution management. Runoff from mining, farming, forestry, and other land uses often contains large amounts of sediments. This material can cloud the water, impede photosynthesis, and clog the gills of marine organisms. coastal ecosystems has been smothered and buried by soils and sand washed into the ocean after strong growing human populations and in the vicinity of coastal mining and dredging operations (Castro and Huber, 2005). Thus, this study would help further understanding of the pollution rate in Brunei Bay and simulate methods in preventing further deterioration.

## 1.4 Study area

Brunei Bay is shared between Brunei Darussalam and the East Malaysian States of Sabah and Sarawak (Figure 1.4). A chain of island including the island of Labuan forms a boundary between the bay and the South China Sea (SCS). Most of the east and south shores of the bay are covered in extensive mangrove forests associated mudflats and sandflats at the mouths of the major estuaries. Due to it being a semi-enclosed area, the water characteristics here is unique and affected by this characteristics.

Monsoonal climate has a strong influenced on the SCS. Brunei Bay is situated within the waters of SCS therefore, experiences a monsoonal climate influenced by the SWM and the NEM (Rosteck *et al*, 1993).

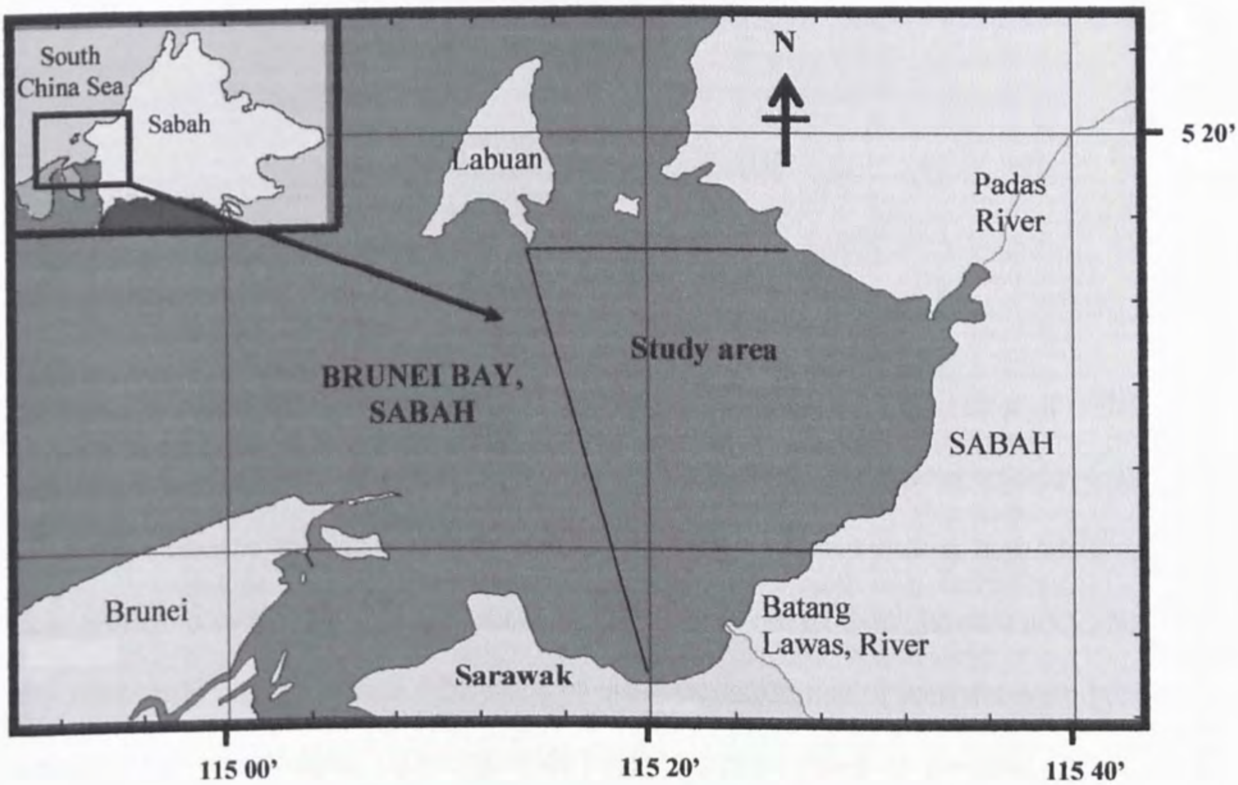


**Figure 1.4** Location of Study area

*Source: Modified from C-Map World for Windows version 3.14, 1996.*

CHAPTER 2

LITERATURE REVIEW

## 2.1 Seawater Properties

### 2.1.1 Salinity

Seawater is about 96.5% water and 3.5% dissolved substances by mass, most of which are salts of various kinds. The total quantity (or concentration) of dissolved organic solids in water is salinity. The ocean salinity varies from 3.3% to 3.7% by mass, depending on factors such as evaporation, precipitation, and freshwater runoff from the continents, but the average salinity given as 3.5 %. Most of the dissolved solids in seawater have been separated into ions. Sodium ion and chloride ion are the most abundant (Garisson, 2005).

### 2.1.2 pH

Another important parameter in seawater is pH. pH is the negative log of the activity or concentration of the hydrogen ion ( Millero, 1996). The pH of seawater is slightly alkaline with its average is about 8. Though seawater is slightly alkaline, it is subject to some variation. in the areas of rapid plant growth, pH will rise because $CO_2$ is used by the plants for photosynthesis and because temperatures are generally warmer at the surface, less $CO_2$ can dissolve and this process is believed to be occur during the SWM. During NEM, with cold temperatures, high pressure and no photosynthetic plants to remove $CO_2$, $CO_2$ will lower the pH of water, making it more acid with depth which $CO_2$ is the source of the respiration from animals and bacteria (Garisson, 2005).

### 2.1.3 Temperature

Seawater temperature varies with depth and latitude. In high latitudes the surface temperature are much lower. The main thermocline may not be present and only seasonal thermocline may occur. The temperature of deep water decrease with a depth of about 300 m; in deep trenches, however *in-situ* temperature increases slowly with depth due to the effect of an increase in pressure (Millero, 1996). Seasonal changes and heat processes from the sun affect the temperature of the seawater according to the latitudes and angle of the sun. Organisms are greatly affected by temperature. Metabolic reactions proceed faster at high temperature and slow down dramatically as it gets colder (Castro and Huber, 2005).

Surface water temperature is mainly affected by the monsoons. During the NEM, when colder masses from higher latitudes flow into the sea, the surface temperature ranges between 26 °C and 27 °C. Higher temperatures of 29 °C to 30 °C are reached during the SWM. The annual variation in surface temperature is larger in the higher latitudes than nearer the equator (Chou and Alino, 1995).

### 2.1.4 Dissolved Oxygen

$O_2$ is a very important gas in the sea because of its role in biological processes. Photosynthesis by plants is restricted to the upper sunlit areas of the sea, but organic matter settles from the surface layer to deeper waters where $O_2$ consumption by animals and bacteria is a major process. Surface water is high in $O_2$ due to exchange with the atmosphere and to photosynthesis. $O_2$ plays a very active role in the chemistry and biology of coastal waters, and its concentration is a major indicator of water quality. in many areas of the world, large quantities of nutrients enter coastal waters from agricultural fertilization and domestic wastes. These nutrients stimulate the rapid growth of phytoplankton. When the organic matter produced from these nutrients settles into deep waters of bays and estuaries, its decomposition can deplete the waters of $O_2$. The results can be fish kills and the formation of hydrogen sulphide gas ($H_2S$), which is poisonous to many types of organisms (Kester, 2003). The effects of $O_2$ depletion on fish populations have, until recently, been badly underestimated (Sindermann, 1996). The amount of $O_2$ in the water also strongly affected organisms through photosynthesis and respiration (Castro and Huber, 2005).

## 2.2 Monsoons

A monsoon is a regional wind that reverses directions seasonally (Duncan, 2005). The word *monsoon* derived from the Arabic *mausim,* which means seasons. A monsoon wind system is one that changes direction seasonally, blowing from one direction in summer and from the opposite direction in winter (Ahrens, 2005). The difference in specific heat capacity between continent sand oceans (and specifically between the large Asian Continent and the Indian Ocean) induced the monsoons, strong seasonal fluctuations in wind direction and precipitation over oceans and continents. The high seasonal variability affects various fluctuations in the environment and its biota which are reflected in marine sediments. Monsoonal precipitation supplies a large volume of fresh water, discharged by rivers from the continents into the sea, with the flow directed by the topography in the region of the water mouths (Niitsuma and Naidu, 2001).

Monsoonal climate has a strong influence on the South China Sea (SCS). Climatic variations in the atmosphere and in the upper ocean of the SCS are primarily controlled by the East Asian monsoon, which follows closely the climatic variations in the equatorial central Pacific (Zhang *et al.,* 1997). The NEM and SWM change the surface current circulation patterns of the sea with predictable regularity. Wind forces are small but constant, while storms and typhoons are confined to the northern and northeastern sector (Chou and Alino, 1995).

The surface circulation in the SCS changes drastically with season in response to the alternating monsoons. The NEM forces a cyclonic gyre covering the entire deep basin with an intensified southward jet along the coast of Vietnam (Wyrtki, 1961; Shaw and Chao, 1994). The SWM drives an anticyclonic gyre mainly in the southern basin. The summer coastal jet separates from the coast of Vietnam at around 12 $^0$N and flows towards the Luzon Strait. Localized upwelling is forced by the circulation gyres in areas off Vietnam during SWM and off the Sunda Shelf and western Luzon during the NEM (Chao *et al*., 1996a; Shaw *et al*., 1996; Udarbe-Walker and Villanoy, 2001).

It is conceivable that the biogeochemistry of the SCS could respond to the alternating monsoons in a way similar to the monsoon-driven Arabian Sea biogeochemistry (Smith *et al*., 1998; Burkill, 1999). For example, Tang *et al*., (1999) attributed the recurrence of a winter phytoplankton bloom off northwest Luzon, revealed in the coastal zone colour scanner (CZCS) data, to upwelling under the NEM (Shaw *et al*., 1996; Udarbe-Walker and Villanoy, 2001). However, unlike the Arabian Sea, the SCS has received relatively little attention in the biogeochemical research. Under the influence of two nearby climate driving engines, the SCS would be an ideal site to study the sensitivity of physical and biogeochemical conditions to climate changes.

The monsoons cause a rainy and dry season and consequently a strong annual variation. But with the monsoons also the whole circulation is changed and water masses of low and high salinities are interchanged. These interactions between different factors and influences, the geographical structure, the runoff from the rivers, the rainfall, the evaporation and the circulation result in a highly complicated distribution of the salinity in these waters and in strong variations (Wyrtki, 1961).

Monsoon can affect the salinity, and the difference between the evaporation and precipitation occurring at different latitudes controls the surface salinities. We can determine the difference of the salinity between the two monsoons. During SWM, the salinity is expected to be high because of the evaporation rate during that season, compared to the salinity during NEM which is generally low because of high rainfall and river runoff. Salinity is maintained at around 33 ‰ to 34 ‰ but the near shore waters usually have lower salinities of around 29 ‰ because of freshwater runoff from land, particularly on the rainy seasons. The salinity is extremely variable in contrast to the uniform temperature in this region, which is when the rainy and dry season and consequently strong annual variation. But with the monsoons, the whole circulation is changed and water masses of low and high salinities interchanged (Wyrtki, 1961).

The interactions between different factors and influences, the geographical structure, the runoff from the rivers, the rainfall, the evaporation and the circulation result in highly complicated distribution of salinity in these waters and in strong variation ( Chou and Alino, 1995). It is convincible that the biogeochemistry of the SCS could respond to the alternating monsoons in a way similar to the monsoon-driven Arabian Sea biogeochemistry (Smith *et al.*, 1998; Burkill, 1999).

## 2.3 Weather and Climate

The weather and climate condition of an area determines the fluctuation in seawater properties. Weather refers to the conditions in the atmosphere at a given place and time; it includes temperature, atmospheric pressure, precipitation, cloudiness, humidity and wind. Weather changes from one hour to the next and from one day to the next (Solomon *et al.*, 2002). Climate comprises the average weather conditions plus extreme (record) that given

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