SEDIMENT CHEMISTRY IN MANGROVE AREA: SEDIMENT PROFILE OF pH, SULPHATE AND WATER SOLUBLE ALUMINIUM

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ABSTRACT

The Salut-Mengkabong Lagoon is rich in marine life such as crabs, oysters, prawns and fish, among other river. Due to the increase of the human population of the Mengkabong villages, logging activities were carried out to accommodate the expansion of the villages as well as setting up of prawn and fishponds have contributed to the deterioration of environment and marine resources at Salut-Mengkabong. A study was carried out to investigate the physico-chemical parameter, the concentration of sulphate (SO_4^{2-}) and water soluble aluminium (Al) of sediment in Mengkabong Lagoon, in Tuaran District, Sabah. This is to understand the chemistry of mangrove sediment and these parameters were related to the depth distribution. The properties of mangrove sediments were compared between undisturbed and disturbed area. The undisturbed area was the area is no development was carried out and the mangroves species there were conserved and remain undisturbed. Moreover, it was located at the entrance of the path to the lagoon where seawater inflow influences in the sediments. Whereas, the disturbed area are defined as an area where the mangroves species were being disturbed. Also, it was situated behind a residential area and is least affected by seawater. The pH was analyzed using Mettler Toledo 320 pH meter with two calibration points (pH 4 & 7) after extraction in water. Concentration of SO_4^{2-} was analyzed using UV Spectrophotometer by turbidimetric method. Water soluble Al was analyzed using Atomic Absorption Spectrometer (AAS) after extracted in water. The mean of pH was at a wide range which is from 6.37 to 7.33 for undisturbed and undisturbed area. The mean concentration of SO_4^{2-} was at the range of 11.07 to 19.10 mgg^{-1}. The concentration of water soluble Aluminium was very low in Mengkabong Lagoon which is in the range from 0.033 to 0.318 μgg^{-1}.

KIMIA SEDIMEN DI KAWASAN PAYA BAKAU: PROFIL SEDIMEN TENTANG pH, SULFAT DAN ALUMINIUM TERLARUT

ABSTRAK

Teluk Salut-Mengkabong kaya dengan hidupan marin seperti ketam, tiram, udang dan ikan berbanding dengan sungai yang lain. Dengan penigkatan populasi manusia di kampung-kampung Mengkabong, aktiviti pembalakan telah dijalankan untuk memenuhi pengembangan kampung-kampung itu. Tambahan lagi, pembentukan kolam-kolam udang dan ikan telah menyumbang kepada kemerosotan kualiti alam sekitar dan sumber marin di Salut-Mengkabong. Kajian telah dijalankan untuk menyelidik parameter fiziko-kimia, kepekatan sulfat, dan kepekatan aluminium bagi sedimen di Teluk Mengkabong, daerah Tuaran, Sabah. Ini adalah untuk memahami sifat kimia bagi sedimen di paya bakau dan parameter-parameter ini telah dikaitkan dengan pengagihan kedalaman. Ciri-ciri sedimen paya bakau ini telah dibandingkan di antara kawasan terganggu dan kawasan tidak terganggu. Kawasan tidak terganggu merupakan kawasan yang tidak menunjukkan sebarang pembangunan dan spesies paya bakau di sana adalah dibawah jagaan dan tinggal tidak terganggu. Lagipun, kawasan ini terletak di jalan masuk ke teluk itu di mana pengaliran masuk air laut mempengaruhi sedimen di sana. Manakala, kawasan terganggu didefinisikan sebagai kawasan di mana spesies paya bakaunya telah mengalami gangguan. Juga, ia terletak di belakang kawasan perumahan dan merupakan kawasan yang paling kurang dikesani oleh air laut. Mettler Toledo 320 pH meter dengan dua titik kalibrasi (pH 4 & 7) digunakan untuk menganalisis pH selepas rentapan dalam air. Spektrofotometer UV digunakan untuk menganalisis kepekatan sulfat dengan kaedah turbidimetrik. Aluminium terlarut dianalisis dengan menggunakan Spektrometer Serapan Atomik (*Atomic Absorption Spectrometer*, AAS) setelah rentapan dalam air. Nilai min pH di kawasan terganggu dan kawasan tidak terganggu adalah dalam julat yang lebar, dari 6.37 ke 7.33. Nilai min bagi kepekatan sulfat adalah dalam julat 11.07 ke 19.10 mgg^{-1}. Kepekatan Aluminium terlarut di Teluk Mengkabong adalah sangat rendah di mana dalam julat 0.033 ke 0.318 μgg^{-1}.

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%	percent
°	degree
°C	degree Celsius
$<$	less than
$[H^+]$	concentration of hydrogen ion
cm	centimeter
g	gram
ha	hectares
km^2	kilometer square
mL	milliliter
mm	millimeter
mgg^{-1}	milligram per gram
mgL^{-1}	milligram per liter
μgg^{-1}	microgram per gram
μgL^{-1}	microgram per liter
µm	micrometer
nm	nanometer
ppm	parts per million
AAS	Atomic Absorption Spectrometer
ASS	Acid Sulphate Soils
Al	Aluminium
Al^{3+}	Aluminium ion
$BaCl_2$	Barium Chloride
$BaCl_2.2H_2O$	Barium Chloride crystalline
$BaSO_4$	Barium Sulphate
C	Carbon
CEC	Cation Exchange Capacity
CH_2O	Formaldehyde
Cl^-	Chloride ion
CO_2	Carbon Dioxide
conc.	Concentration

DD	Distilled or Deionized
DMS	Dimethylsulphide
E	East
EPD	Environmental Protection Department
FeS_2	Pyrite
$FeSO_4$	Ferrous iron
$Fe_2 (SO_4)_3$	Ferric iron
GF-AAS	Graphite Furnace- Atomic Absorption Spectrometry
GPS	Global Positioning System
GIS	Geographic Information System
h	Hour
H^+	Hydrogen ion
H_2O	Water
H_2S	Hydrogen Sulphide
H_2SO_4	Sulphuric acid
HCl	Hydrochloride acid
HCO_3^-	Bicarbonate ion
H_2CO_3	Carbonic acid
HNO_3	Nitric acid
KKIP	Kota Kinabalu Industrial Park
LC_{50}	The concentration that causes mortality in 50 % of the organisms tested estimated by graphical or computational means
log	Logarithm
N	North
NaCl	Sodium Chloride
O_2	Oxygen
pH	Hydrogen ion concentration
QC	Quality Control
S	Sulphur
SO_4^{2-}	Sulphate
SPSS	Statistical Package for Social Sciences
Vs	Versus

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Mangroves (or wetlands) are defined by the Convention of Wetlands of International Importance as: "Land inundated with temporary or permanent water that is usually slow moving or stationary, shallow, either fresh, brackish, or saline, where the inundation determines the type and productivity of sediments and the plant and animal communities" (Putrajaya Holdings Sdn. Bhd, 1999).

Mangroves are saltwater forests that grow on coastal mud flats in low latitude areas around the globe, usually in shallow shorelines where silt is deposited by streams and accumulates with the movement of the sea (Ripley, 1964). They form a unique ecosystem in an environment that is in constant flux. In order to deal with salinities and water levels that can change on a daily basis, the variety of plants collectively known as mangroves has evolved many features that allow them to cope with this environment. Mangroves have developed many adaptations that given them wide ranges of tolerance. These adaptations result in geochemical modifications in the sediment. Additionally, climate, tidal flooding, vegetation evolution, bioturbation and organic matter content are parameters that also contribute to the complexity of the geochemistry of mangrove inhabited deposits (Marchand, *et. al.*, 2004).

Mangrove Forest covers a greater area in Sabah than in other states in Malaysia, occurring mostly along the eastern and southeastern coasts of the state. The most common species of mangrove trees is the *Rhizophora sp.* and *Avicennia sp.*, often growing in almost pure stands. Although large scale harvesting of mangrove chips for export was phased out in 1986, mangroves are widely used locally for piling, firewood and charcoal production. Mangroves are also important in physically protecting the coastlines and the spidery roots of the mangroves hold the sediments in place, providing an important habitat for fish fry and other aquatic animals (Anon, 2005).

Mangroves are characterized by having hydric soils (soil that has been wet long enough to have oxidized reactions). Mangrove sediments, however, are neutral to slightly acidic due to the sulphur-reducing bacteria, and the presence of acidic clays. There are mangroves with very acidic brackish waters, probably due to the aeration of sediment sulphates, forming sulphuric acid (Ng & Sivasothi, 2001). Mangrove sediments (or acid sulphate soils) are extensive throughout the world except in major deserts (Gutherie, 1985). These sediments are rich in pyrite (FeS_2). Sediments underlying mangroves do not present any threat to the environment if they are left undisturbed. However, when these sediments are exposed to oxygen, the sulphide in the sediment (from pyrite, FeS_2) is oxidized to sulphuric acid.

Acid sulfate soils (ASS) are soils or sediments containing highly acidic soil horizons or layers affected by the oxidation of iron sulfides (termed actual ASS), and/or soils or sediments containing iron sulfides or other sulfidic materials that has not been exposed to air and oxidized (termed potential ASS) (Powell & Martens, 2005). During rainfall events, the toxic leach ate from ASS oxidation can be washed into waterways causing or contributing to fish kills, fish diseases, habitat degradation and modification, death of aquatic organisms, poor plant productivity, growth of exotic weeds, corrosion of infrastructure, aluminium flocculation, groundwater contamination, secondary ferrous oxidation and acid generation, estuarine acidification and extensive iron staining. Such events pose a significant threat to the quality of coastal waters and ecosystems (Ahern, *et. al.*, 2002).

According to the Environmental Indicator Report written by Environmental Protection Department (EPD) of Sabah, the Mengkabong mangroves experienced a 15% decrease from 1991 to 2000. The mangroves covered 12.6 km^2 in 1991, but dropped to 10.7 km^2 in 2000. Future development plans such as housing and aquaculture projects already alienated the land within the mangroves and it is foreseeable that eventually little original mangrove forest will remain. By 2020, it can be predicted that mangroves will cover only 3.8 km^2, which corresponds to a 70% decline (Anon, 2003).

Nowadays, Mengkabong lagoon is facing pollution problems which are caused by human impacts and development. Those sources of pollution that have been identified are: industrial sources near Salut-Mengkabong lagoon, domestic sources generated by households such as the water villages in the lagoon and lastly, land clearing causing siltation and sedimentation. Hill cutting in 1998 had caused erosion that smothered areas of mangroves/ mudflats and significantly impacted the surrounding biodiversity. Furthermore, Kota Kinabalu Industrial Park (KKIP) is being developed in parts of the catchments near the lagoon and without proper management of land and control of pollution; the development of KKIP could also cause negative impacts to the lagoon (Anon, 2003).

1.2 OBJECTIVE

This research is carried out to accomplish the following objectives:-

- To analyze and assess the mangrove sediment profiles of pH, sulphate (SO_4^{2-}), and water soluble Aluminium (Al) at Mengkabong Lagoon, Tuaran.
- To compare the pH, concentration of sulphate (SO_4^{2-}), and concentration of water soluble Aluminium (Al) of sediments in undisturbed area with disturbed area in the Mengkabong Lagoon, Tuaran.

CHAPTER 2

LITERATURE REVIEW

2.1 DEFINITION OF WETLANDS

Wetlands have different meanings to different people depending on their background, exposure, knowledge, and political stand. Many definitions for wetlands have been proposed and utilized over the years. There are three factors necessary for a peace of land to be classified as a wetland. These are the hydrology (how much flooding or soil saturation), presence of hydrophytes, and hydric soils (soils saturated long enough for the substrate to become deficient in oxygen). In other words, three characteristics define wetlands: hydrology, hydric soils, and hydrophytic plants. Among the most widely accepted definitions is that of Cowardin *et al.,* (1979) which was adopted by the U.S. Fish and Wildlife Service.

> *"Land where an excess of water is the dominant factor determining the nature of sediment development and the types of animals and plant communities living at the sediment surface. It spans a continuum of environments where terrestrial and aquatic systems intergraded."*

This definition comprises three aspects: - water, sediments, and organisms, which are accepted by wetland scientists as the basis for recognizing and describing wetlands environments.

Wetlands are widespread features of the landscape throughout the world. Three distinguishing features set wetlands apart from other landscape units:

i. The presence of water at or near the land surface,
ii. Unique sediment conditions that are most often characterized by low oxygen content, and
iii. Specialized biota (most obviously plants) that is adapted to growing in these environments (Keddy, 2000; Mitch & Gosselink, 2000).

2.2 PEATLANDS

Peatlands referred to as 'organic wetland', are a large subset, and probably the most widespread, group of wetlands. The dominance of a living plant layer and thick accumulations of preserved plant detritus from pervious years' growth sets peatlands apart from mineral wetlands, which lack any substantial thickness and accumulation of organic remains. Not surprisingly, it is therefore the presence of peat that is the key feature of peatlands. Lakes and other non-wetland open water bodies may contain peat, but this only occurs in limited areas or where organic remains have been carried in by water movement (Charman, 2002).

According to Charman (2002), most peatlands begin their existence as mineral wetlands and become organic wetlands over time, either naturally through succession processes or with the assistance of humans or some other factors.

2.3 WETLANDS CLASSIFICATIONS

Table 2.1 Main terms used in the English-language peatland literature.

Wetland	Land with the water table close to or above the surface or which is saturated for a significant period of time. Includes most peatlands but also ecosystems on mineral substrates, flowing and shallow waters.
Peatland	Any ecosystem where in excess of 30-40 cm of peat has formed. Includes some wetlands but also organic soils where aquatic processes may not be operating (e.g. drained or afforested peatlands).
Mire	All ecosystems described in English as swamp, bog, fen, moor, muskeg and peatland (Gore, 1983), but not use synonymously with peatlands (Heathwaite, *et al*., 1993). Includes all peatlands, but some mires may have mineral substrate.
Fen	A mire which is influence by water from outside its own limits.
Bog	A mire which receives water solely from rain and/ or snow falling on to its surface.
Marsh	Loose term usually referring to a fen with tall herbaceous vegetation often with a mineral substrate.
Swamp	Loose term with very wide range of usage. Usually referring to a fen and often implying forest cover.

(Source: Adapted from Charman, 2002)

2.3.1 Bogs

The word "bog" has been used as a definition of soft, spongy ground since prior to 1450 (Barnhart, 1988). Barnhart (1988) reports the word to be of Irish and Gaelic origin. The term "bog" can be used to describe either a landform or a plant community. Bates and Jackson (1984) give definitions based on being a landform and a plant community; Parker (1989) defines a bog as a plant community with a permanently waterlogged peat substrate. Damman and French (1987) give a good definition that begins to show the interrelationship between the land and the vegetation. They define a bog as: *"a nutrient-poor, acid peatland with vegetation in which peat mosses, ericaceous shrubs, and sedges play a prominent role"*. From these definitions, it becomes apparent that vegetation and water are critical and interrelated requirements for a bog environment.

Bogs are strictly *ombrotrophic* systems (Charman, 2002) and one of North America's most distinctive kinds of wetlands. They are characterized by spongy peat deposits, acidic waters, and a floor covered by a thick carpet of *Sphagnum* moss. Bogs receive all or most of their water from precipitation rather than from runoff, groundwater or streams. As a result, bogs are low in the nutrients needed for plant growth, a condition that is enhanced by acid forming peat mosses. Over time, many feet of acidic peat deposits build up in bogs of either origin. The unique and demanding physical and chemical characteristics of bogs result in the presence of plant and animal communities that demonstrate many special adaptations to low nutrient levels, waterlogged conditions, and acidic waters (U.S. Environmental Protection Agency, 2005a).

2.3.2 Fens

Fens are peat-forming wetlands that receive nutrients from sources other than precipitation: usually from upslope sources through drainage from surrounding mineral soils and from groundwater movement. Fens differ from bogs because they are less acidic and have higher nutrient levels. They are therefore able to support a much more diverse plant and animal community. These systems are often covered by grasses, sedges, rushes, and wildflowers. Some fens are characterized by parallel ridges of vegetation separated by less productive hollows. The ridges of these patterned fens form perpendicular to the down slope direction of water movement. Over time, peat may build up and separate the fen from its groundwater supply. When this happens, the fen receives fewer nutrients and may become a bog (U. S. Environmental Protection Agency, 2005b).

2.3.3 Marshes

Marshes defined as wetlands are frequently or continuously inundated with water, and characterized by emergent soft-stemmed vegetation adapted to saturated soil conditions. There are many different kinds of marshes, ranging from the prairie potholes to the Everglades, coastal to inland, freshwater to saltwater. All types receive most of their water from surface water, and many marshes are also fed by groundwater. Nutrients are plentiful and the pH is usually neutral leading to an abundance of plant and animal life (U.S. Environmental Protection Agency, 2005c). Emergent wetlands are better known as marshes. They are usually dominated by

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