Faculty of Resource Science and Technology

BENTHIC DIATOMS COMPOSITION OF SUNGAI SARAWAK KANAN AND ITS TRIBUTARIES

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DECLARATION

No portion of the work referred to this dissertation has been submitted of an application for another degree of qualification of this or any other university or institution of higher learning.

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LIST OF ABBREVIATIONS

Abbreviation	Description
m	meter
mL	mililitre
ºC	degree Celsius
H_2O_2	hydrogen peroxide
DO	dissolved oxygen
μS/cm	micro Siemen per centimeter
ppm	part per million

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Benthic Diatoms Composition of Sungai Sarawak Kanan and Its Tributaries

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ABSTRACT

This study aimed to document the composition of benthic diatoms at Sungai Sarawak Kanan and its tributaries. Samplings were done in November 2013, January 2014 and March 2014 at three stations namely Sungai Pedaun, Sungai Bijuray and Sungai Sarawak Kanan. Diatoms samples were cleaned with Hydrogen Peroxide oxidation method and mounted with high refractive medium Naphrax® on a glass slide to facilitate cell identification. A total of 21 genera were recorded in this study with the most number at Station 1. There are three common genera were found at each station throughout the study, which are *Achnanthes*, *Gomphonema* and *Navicula*. The correlation among physico-chemical water quality parameter with some diatom genus was identified to have strong significant correlation with $p< 0.05$ (Pearson's Correlation). The physico-chemical water quality parameter is measured in range of 5.83 ppm to 11.79 ppm for dissolved oxygen (DO), 25.0 ºC to 29.73 ºC for temperature, 7.02 to 7.88 for pH, and 37.9 µS/cm to 114.90 µS/cm for conductivity.

Keywords: benthic diatoms, genera, physico-chemical water quality parameter, strong significant correlation

ABSTRAK

Kajian ini bertujuan untuk mendokumentasikan komposisi diatom bentik di Sungai Sarawak Kanan dan cawangannya. Persampelan telah dilakukan pada bulan November 2013, Januari 2014 dan Mac 2014 di tiga stesen iaitu Sungai Pedaun , Sungai Bijuray dan Sungai Sarawak Kanan. Sampel diatom telah dibersihkan dengan kaedah pengoksidaan menggunakan Hidrogen Peroksida dan dilekatkan pada slaid kaca dengan Naphrax ®, medium biasan tinggi untuk memudahkan pengecaman sel. Sebanyak 21 genus telah direkodkan dalam kajian ini dengan bilangan yang paling banyak di Stesen 1. Terdapat tiga genus yang biasa ditemui di setiap stesen sepanjang kajian ini, iaitu Achnanthes , Gomphonema *dan* Navicula . *Hubungan di antara parameter fiziko –kimia air dengan beberapa genus diatom telah dikenalpasti mempunyai hubungan yang signifikan kuat pada $p< 0.05$ (Korelasi Pearson). Kepekatan oksigen terlarut (DO) adalah dalam julat 5.83 ppm ke 11.79 ppm, parameter suhu dalam julat 25.0 º C sehingga 29,73 º C, pH dalam julat 7.02 sehingga 7.88 dan kekonduksian dalam julat 37.9 µS / cm sehingga 114.90 µS / cm.*

Kata kunci: bentik diatom, genera, hubungan singnifikan yang kuat, parameter fiziko-kimia air

1.0 INTRODUCTION

Aquatic floras especially algae is an important primary producers in aquatic ecosystem as they are photosynthetic. Algae exist as planktonic (move freely in water column), benthic (attached to substrate) or both. Benthic algae are also called periphyton and may consist of green algae, cyanobacteria, bacteria and benthic diatoms.

Diatoms are member of class Bacillariophyceae of division Chrysophyta. They are microscopic unicellular algae with size range from 5µm to 500µm. Their unique characteristics are the impregnation of large amount of silica on their cell wall and the possession of two parts of the skeleton (Cupp, 1943).

Benthic diatoms are a major food source for grazers such as crustaceans, juvenile fish and insect larvae. They formed brownish film that can be seen on the surface of rocks and pebbles that are exposed or submerged in water. Currently, the algae have also been used as a tool in biological monitoring of water quality in many countries. Their distribution and variation are more or less affected by chemical, physical and biological conditions of the environment (Mitbavkar and Anil, 2002) because benthic diatoms have sensitivity to a wide range of environmental variables. In addition, Pan *et al*. (1999) mentioned that benthic diatoms are more likely to be influenced by local environmental condition than broad-scale factors.

Assemblages and distribution of benthic diatoms in river and lotic system are affected often by water chemistry (particularly pH, ionic strength and nutrient concentration), substrate, current velocity, temperature, light and grazing (Patrick & Reimer, 1966; Pan et al., 1996; Potapova & Charles, 2002).

Studies of benthic diatoms in Malaysia and Sarawak have been previously been carried out. Maznah and Mansor (2002) had done benthic study in Penang River Basin. Several studies of benthic diatoms have also been done in Sarawak. One of them was about pennate diatom in Sarawak estuarine waters (Farah *et al*., 2011). Other studies included Final Year Project by Marlena (2005) who studied on the microalgae including diatoms in mangrove area in Kuala Paloh. Firdauz (2006) carried out a study on benthic diatoms at Sungai Sarawak Kiri while Helen (2006) did a similar study at Sungai Semadang. Siti (2006) and Norseila (2008) also did a similar study on benthic diatoms at Sungai Sarawak and Sungai Kuap, Sarawak respectively. However, until recently, there is still not much study and insufficient data on benthic diatoms composition at Sungai Sarawak Kanan located in Bau, Sarawak. Thus current study was carried out on the benthic diatoms composition at Sungai Sarawak Kanan and its tributaries. The objectives of this study were to:

1) document the generic compositions of benthic diatoms in Sungai Sarawak Kanan and its tributaries.
2) relate the selective water parameters such as temperature, pH, conductivity and dissolved oxygen with the percentage of occurrence for each genus of diatoms present.

2.0 LITERATURE REVIEW

Diatoms are microscopic unicellular organisms, which lives solitary but sometimes form colony or chains of cells and can be found both in marine and freshwater ecosystems. As they are photosynthetic organisms, they are known as one of the vital primary producers and constitute the base of major food webs in aquatic habitat. Diatoms are one of the most important oxygen producer in aquatic ecosystem that about 40% of oxygen in the ecosystem (Spaulding *et al.*, 2010). According Round *et al.* (1990), diatoms belonged to class Bacillariophyceae, have over 260 genera with more than 100 000 species.

Siliceous cell wall or frustule, particular photosynthetic pigments and oil or chrysolaminarin storage products have been the unique characteristics of diatoms (Soininen, 2004). The basic structure of the frustule of a diatoms is two valves, with each edge is connected to a circular piece of silica known as girdle band or cingulum (Patrick and Reimer, 1966). The two valves fit each other like a petri dish with one part slightly smaller than the other. As a result of their mode of reproduction which is via cell division, one valve is older than the other valve, called epitheca associated with the cingulum and is slightly bigger (Cupp, 1943; Round *et al*., 1990). The newer valve is slightly smaller called hypotheca.

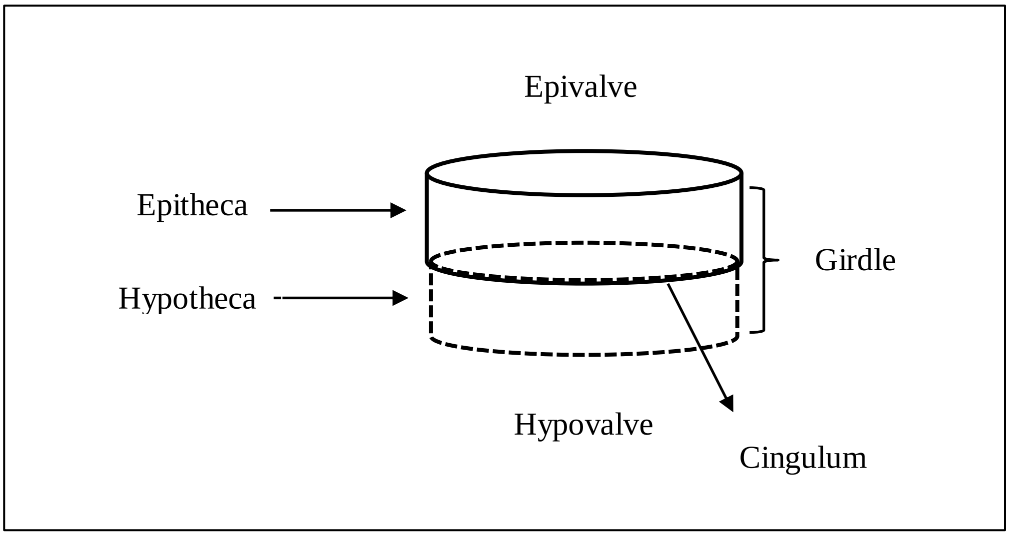

Figure 1: Frustule of diatoms.

The diatoms can be viewed in two aspects; valve view and girdle view (Cupp, 1943). Valve view refers to the view of the surface of the valve. Girdle view refers to the side or profile view.

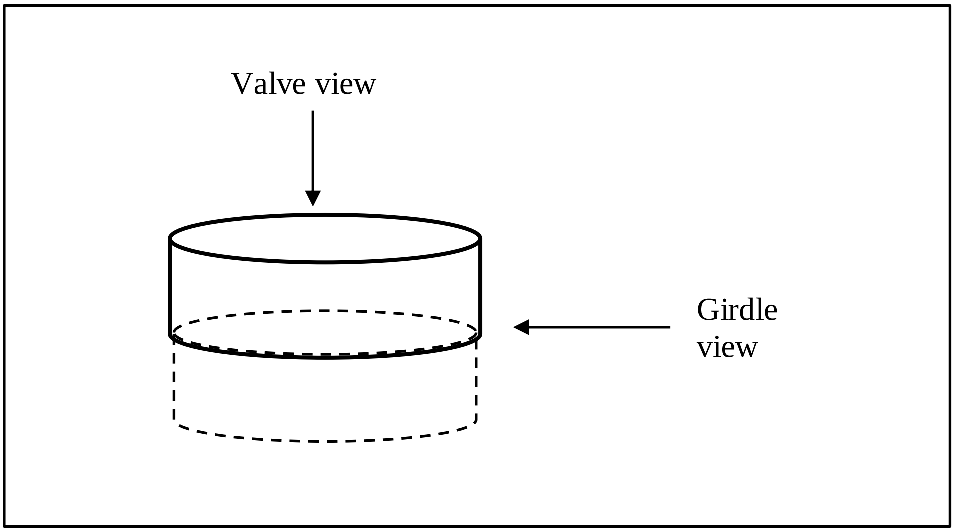

Figure 2: Valve view and girdle view of diatoms.

2.1 Diatoms classification

Diatoms are members of class Bacillariophyceae, Division Chrysophyta. They are further separated into two distinguished order, namely Centrales and Pennales (Hunter, 2007).The Centrales are centric diatoms having radial symmetry and mostly found in marine habitat. The Pennales are pennate diatoms having elongated frustule and bilateral in symmetry.

Diatoms can be either planktonic or benthic. Some do exist in both forms. Diatoms are also classified based on the present of a raphe as its characteristics. Pennate diatoms are divided further into two groups based on the presence of raphe; raphid (diatoms possessing raphe) and araphid (diatoms that does not possess raphe) (Mock & Medlin, 2012).

Patrick and Reimer (1966) stated that the pattern and structure of the valve that the systematics of most taxa of diatoms are largely based. On the other hand, Round *et al*. (1990) stated that diatoms classification depends on a great extend upon the intricacies of pore structure, and the arrangement of the wall organelles (portulae, ocelli, striae, raphe, etc).

2.3 Habitat of diatoms

Diatoms exist in marine and freshwater habitat, and they can be planktonic, benthic or both. Benthic diatoms usually form brown biofilm on rocks or other substrata. Benthic diatoms also inhabits in sediments and surface of sediments. Therefore, habitat of diatoms can be divided into three types: aerial habitat, soil habitat and aquatic habitat (Patrick, 1977; Lokman, 1991).

Lokman (1991) mentioned that aerial habitat diatoms are diatoms species that can survived in unfavourable condition such as flood and dry season. Patrick (1977) stated that diatoms species inhabiting aerial condition must be able to endure more vigorous environment change such as extreme changes in temperature than those live in water. The diatoms living in this habitat are exposed to air and seldom found in aquatic environment but they still need water to grow. In aerial habitat, a further division of sub-habitat was made, which are dry aerial and moist aerial habitat as mentioned by Patrick (1977).

Dry aerial condition is habitat that experienced great fluctuation in moisture, such as on dry rocks, dry moss and dryer spray zones (Patrick, 1977). Moist aerial habitat such as wet rock and moss, caves, snow and ice and spray or surf zone of lakes and rivers (Patrick, 1977). Patrick (1977) and Lokman (1991) stated that only several species of diatoms can survived this extreme condition, therefore only a small specialized group are found in aerial habitat. Some of the members of the specialized group are *Cymbella*, *Navicula*, *Eunotia* and *Achnanthes* species.

Soil habitat diatoms consist of small size diatoms species belonging to Naviculales and Bacillariales group. These diatoms able to survive in such habitat because of the presence of raphe that enables them to move and dig into the sediment when the sediment surface dries up (Lokman, 1991). They obtained nutrients from interstitial space through cell absorption. According to Lokman (1991), common genus of diatoms found in soil habitat are *Navicula, Hantzschia*, and *Pinnularia*.

Aquatic habitat includes ponds, lakes, streams and estuaries. Diatoms that inhibit this habitat can be planktonic or benthic. Benthic diatoms are also divided into four communities based on their substrata (Lokman, 1991). The four communities are epilithic, epiphytic, epipsammic and epizoic communities.

Epilithic community refers to diatoms that grow on rocks, epiphytic community grows on plants, epipsammic community grows on sand grains and epizoic community grows on animals (see Table 1). Cahoon (1999) on the other hand, described an addition of benthic diatoms community which are epipelic (grow on rock), endopelic (grow on inside sediment), endolithic (grow inside rock) and psychrophilic (grow on ice). Excluding epipsammic diatoms which consist of small appressed species and species having very short stalks, they all have overlapping life-forms (Round *et al.*, 2007).

Table 1: Communities of benthic diatoms

Communities of benthic diatoms	Description
Epilithic	Grows on rocks
Endolithic	Grows inside rocks
Epipsammic	Grows on sand grains
Endopelic	Grows inside sediments
Epipelic	Grows on mud
Epizoic	Grows on animals
Epiphytic	Grows on plants or macrophyte
Psychrophilic	Grows on ice

2.3 Motility of diatoms

Lee (1989) mentioned that some diatoms are able to glide over the surface of a substrate, leaving behind a mucilaginous trail. Gliding is restricted to those pennate diatoms with a raphe and those centric diatoms with labiate processes (Lee, 1989). Patrick and Reimer (1966) mentioned that active external movement of diatoms is made possible by rotation of the cytoplasm in the raphe. This statement supported the idea mentioned by Lokman (1991) that only diatoms with raphe have the ability to move.

Lokman (1991) mentioned that pennate diatoms having raphe have gliding movement, while some araphid pennate diatoms have limited movement. The direction and path of their movement also depends on the structure and shape of the raphe (Nultsch, 1956; Lee, 1989; Lokman, 1991). Some araphids diatoms have slow movement. The motility of diatoms are influenced by temperature (Hopkins, 1963), light (Nultsch, 1971), oxygen, dissolved chemical (Lokman, 1991) and specific day time (Harper, 1967).

Cupp (1943) stated that the movement is frequently jerky, sometimes creeping and steadily. Diatoms move by propelling themselves backward and forward as mentioned by Cupp (1943). Single cells may move freely, while cells in colony move together as one unit or back and forth upon one another (Cupp, 1943).

2.4 Reproduction of diatoms

The most common diatoms reproduction is via cell division or mitosis producing two daughter cells. In this cell division, the daughter cells inherit the epitheca from the parent cell while a new hypotheca is synthesized by the daughter cell. As a result, one of the daughter cell is smaller than the parent cell, while the other has the same size of the parent cell (Moen, 2013). After a few cycles of mitosis, the cell size decreases, therefore they undergo sexual reproduction. Sexual reproduction occurs dependant to cell size and environmental condition (Patrick & Reimer, 1966; Mizuno & Okuda, 1985). In this sexual reproduction, auxospore is produced to restore the maximum size of diatoms and a type of rejuvenation (Cupp, 1943). The auxospores are formed by fusion of two gametes, male and female. Gametes can be divided into two types; anisogamy and isogamy. Anisogamy refers to two gametes with different morphology. Female gamete is larger and non-motile while male gamete is smaller, flagellated and motile. Isogamy on the other hand, refers to two gametes of similar morphology.

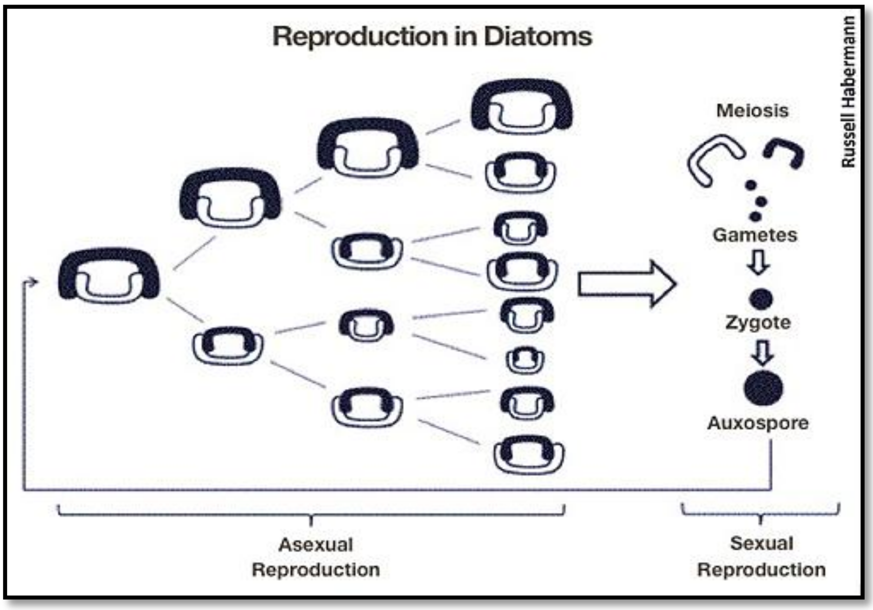

Figure 3: Reproduction of diatoms. (Moen, 2013).

In centric and gonoid diatoms, the male gamete is motile while the female gamete is non-motile (Lee, 1989). For pennate and trellisoid diatoms, both gametes are non-flagellated (Lee, 1989).

2.5 Diatoms as biological indicator

Recently, many countries have used diatoms to monitor environmental condition and water quality. Diatoms are more likely to be influenced by local environmental factors than broad-scale climatic, vegetation, and geological factors (Soininen, 2004).

They are more suitable as biological indicators as they have well known ecology, high cell density (Soininen, 2004). In addition, they have a shorter life cycle and a nature as primary producers. Diatoms have the sensitivity to pH, conductivity, turbidity, BOD and DO.

Potential factors that influence the algal communities include light, temperature, current, substrate and water chemistry (Hynes, 1970). The pH often changes in a natural ecosystem. This change of pH has major impact to aquatic organisms as they show the alkalinity and acidity of the water, types of soil and types of rocks. Conductivity of water shows the amount of ion concentration in the water. Some diatoms prefer high ionic concentration, some prefer lower ionic concentration. Salinity and concentration of major ions have a strong influence on diatoms distribution (Potapova & Charles, 2003).

2.6 Previous studies on diatoms in Malaysia

Several studies of algae and diatoms as biological indicator have been practiced to monitor water quality. Europe (Hening *et al*., 2006), Brazil (Bere & Tundisi, 2010), and Ontario (Belore *et al*., 2002) are examples of countries that use diatoms for bio-monitoring of water pollution. Several studies have been done in Malaysia using diatoms to monitor water pollution such as in Penang River Basin (Maznah & Mansor, 2002).

Diatoms have become a right candidate as biological indicator as they have specific response to pollution level. It's either they die or manage to survive and live. Furthermore, different species of diatoms have different toleration level to pollution and water chemistry such as pH, salinity, conductivity and nutrient concentration (Hynes, 1970; Whitton, 1975; Hunter, 2007), water velocity, light and grazing (Wellnitz & Rader, 2003).

Previous studies of diatoms as environmental indicators resulted in correlation of diversity, abundance and species richness of diatoms with pollution level. Clean streams that are usually headwater and upstream which have little or no exposure to organic waste have a higher diversity of diatoms compared to downstream (Maznah & Mansor, 2002). This is due to the capability of diatoms species to tolerate and adapt to the environmental condition (Wu, 1989; Maznah & Mansor, 2002). As they are acutely sensitive to environmental changes and pollution, only certain taxa or genus of diatoms can survive and dominate the habitat.

In Sarawak, several studies of diatoms have been done. One of them is about pennate diatom in Sarawak estuarine waters (Fareha *et al*., 2011). Study of microalgae, including diatoms has also been done in mangrove area in Kuala Paloh by Marlena (2005).

Benthic diatoms studies have also been previously carried out in Sungai Sarawak Kiri (Firdauz, 2006) and Sungai Semadang (Helen 2006).

3.0 MATERIALS AND METHODS

3.1 Study site

The study was conducted at 3 stations; Sungai Sarawak Kanan in Bau, Sarawak and its tributaries namely Sungai Bijuray and Sungai Pedaun (Figure 4) and their coordinates are shown in Table 2. The sampling was done once at two monthly intervals starting from November 2013 to March 2014.

Table 2: The study Stations and its coordinate.

Station no.	Location	Coordinate
1	Sungai Pedaun	N 01^{o}19'0.04" E 110^{o}05'42.8"
2	Sungai Bijuray	N 01^{o}20'44.2" E 110^{o}06'34.7"
3	Sungai Sarawak Kanan	N 01^{o}24' 55.5" E 110^{o}07'52.7"