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Relationship of Modern Diatoms with Lake Acidification and Water Quality in Nsonji Lake of Nagaland, North-East India

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Abstract

Understanding the relationship of diatoms and water quality is of paramount importance to link it to Holocene Climate Change. Since diatoms are extremely sensitive to environmental changes, they are the obvious choice to study diatom inferred water quality and climate changes. Therefore, sediment samples along with water samples were collected during pre monsoon seasons from the Nsonji Lake of the Nagaland, India to establish the relationship between the diatom and water quality. The Nsonji Lake has circum-neutral pH (around 7) indicating gradual degradation of organic matter leading to acidification of the lake. The surface sediments of the Nsonji Lake revealed the dominance of *Discostella stelligera, Achnanthidium* sp., *Navicula cryptocephala, Navicula radiosa* and *Nitzschia palea.* These diatom species could be used to unravel the acidification history of lake caused by natural and anthropogenic activities. Understanding the past climate dynamics need modern analogue in order to evaluate the important processes relative to Earth's history and built future scenario.

Keywords: Diatoms, Water Quality, Acidification, pH, Organic Matter, Nsonji Lake, Nagaland

Introduction

Diatoms are unicellular algal organisms enclosed in a siliceous cell wall called frustule with overlapping epitheca and hypotheca halves. Diatoms belong to the Division Bacillariophyceae, which is systematically divided into Centrales and Pennales (Simonsen, 1979; John, 2014). It can be found in almost all aquatic habitat, and even in such hospitable places including tree bark and hot springs (Smol and Stoermer, 2010; Williams and Kociolek., 2011). Diatoms have unique structure and shape making them excellent tool to understand the condition of lakes health and environment. Freshwater diatoms have been used to study and reconstruct the environmental condition of lakes because of its sensitivity to the effects of changing pH, nutrient concentration, climate and effects of human disturbances (Venkatachalapathy *et al.*, 2013, 2014; Malik and Saros, 2016). Several workers have studied the investigation of diatom diversity and assessment of water quality (Logannathan *et al.*, 2014; Juare *et al.*, 2014).

The Nagaland State known for its vast hills and diverse culture and is a part of the north eastern states in India. The state is bordered in the north by Arunachal Pradesh, Manipur to the south, Assam to the west and Myanmar to the east. Lakes of Nagaland are not yet being studied for their water quality or for their microfossil contents to infer the present-past trophic status and paleoclimates.

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Study Area

The present study has been carried out on the Nsonji Lake (latitude 25°92'5364" and 25°92'507' N, and longitude 94°10'5823" and 94°10'562"E; Fig. 1) which is located in Sedenyu village, Tseminyu district, Nagaland. Sedenyu village is nearly 50 km from the capital city of Kohima. The Nsonji Lake is located in the village Sedenyu, Tseminyu district, Nagaland popularly known for its biodiversity reserve and as ecotourism destination. It is located 50 km from the capital city Kohima and is surrounded by cities Dimapur, Zunheboto, Wokha and Kohima. The topography of the district is characterised by high and low hill ranges and rich flora and fauna. The maximum depth of the lake is about 7.6 m. The area of the lake is 20,234 sq. m when it is overflowing. Besides its ecotourism, the demarcated area of 18 sq. km is rich in flora and fauna and has acquired wide recognition and has been included in the world map of biodiversity. Kohima, Dimapur, Wokha and Zunheboto are the cities nearby Sedenyu. The major lithology around the lake is grey shale, non calcareous siltstone and silty sandstone belonging to the Upper Disang formation ranging in age from Cretaceous to Eocene.

So far, there exists no record of diatom based water quality study from the Nsonji Lake of Nagaland. The present study reveals the prevailing environmental conditions with regard to understanding the climate driven changes in the lake. This study can be used as a baseline for comparison between water quality parameters and diatom analysis to understand the lake acidification

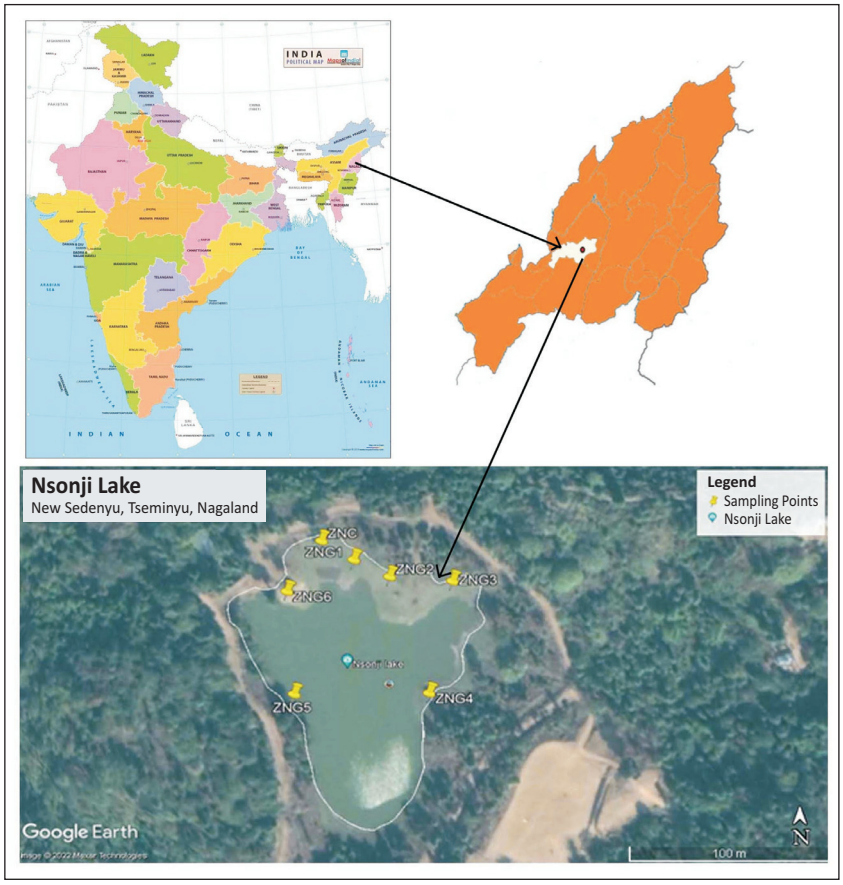

Fig.1. Location Map of the Nsonji Lake, Nagalad, NE India (*Courtesy: Google Earth*)

and water quality along with the climatic variability of the high altitude lakes.

Geology and Stratigraphy

The state of Nagaland (latitude 25°6' N-27°4' N; 93°20' E-95°15' E longitude) in the north-east part of India covers an area of about 16,579 sq.km. Pioneering works by Geological Survey of India, Oil and Natural Gas Corporation and the Directorate of Geology and Mining, Government of Nagaland have laid the foundation of the geology and stratigraphy of Nagaland (Evans, 1932; Mallet, 1876; Ranga Rao, 1983). Overall, the four subdivisions of geotectonic areas of Nagaland consist of various rock formations *i.e.*, the Schuppen Belt, the Inner Palaeogene Fold Belt, the Assam Shelf and the Ophiolitic Complex (Ranga Rao, 1983). Among these the rocks of the Disang Formation are dominant in the central part of Nagaland state (Evans, 1932). The eastern parts of Nagaland along the Disang thrust and the Ophiolite Belt, the rocks of Disang Group are exposed close to the Ophiolite Belt along with epi-metamorphosed slates, phyllites and lenticular limestone bands in the cores of certain major anticlines within the Kohima synclinorium (Ranga Rao, 1983). Overlying the above is an un-metamorphosed sequence of dark-grey splintery shales and massive siltstones with concretions. The rocks of this formation indicate an upper Cretaceous to Eocene age (36.6 million years to over 65 million years old) and a thickness ranging from 2000 to over 3000 m. The nature of the carbonaceous shale is an alteration product of marine algae or seaweed (Mekro, 2014).

Materials and Method

Grab Sampling

The grab sediment samples were collected from the Nsonji Lake in the neatly labelled zip-lock bags to recognize the diatom assemblages. These collected samples were carefully handled and used for diatom analysis.

Water Sampling

The water samples were collected in polythene bottle of 500 ml capacity to understand the hydrochemistry of the Nsonji Lake. The bottles were rinsed 2 to 3 times with the lake water before collecting the samples. Large non-homogeneous matter such as rags, twigs, leaves and other floating materials were avoided. Further various parameters were tested for water quality assessment from the Water Testing Laboratory of the Nagaland Science and Technology Council, Government of Nagaland, Kohima.

Maceration Procedure

The maceration of sediment samples for diatom study and preparation of slides were done using the standard methods of Battarbee (1986). The permanent slides were studied and enumerated using Light Microscope Leica DM 750 under 1000X magnification in the Limnogeology and Applied Micro-

paleontology Laboratory of Department of Geology, RTM Nagpur University, Nagpur.

Results and Discussion

Hydrochemical Analysis

The various parameters obtained from pre- and post-monsoon water samples from the study area are given in Table 1. The hydrochemical parameters like appearance, odor, turbidity, pH, alkalinity, hardness, chloride, iron, ammonia, nitrite, nitrate, phosphate, residual chlorine and total dissolved solids of Nsonji Lake were studied to understand the present water quality. The lake was colourless in appearance during pre-monsoon and brownish during post-monsoon. The pH is a measure of the concentration of hydrogen ions *i.e.*, including the acidic or alkaline condition of water and serves as an important indicator of water quality and suitability of water for various purposes. The pH of the water sample in pre-monsoon was 7 and 6.2 for post-monsoon. In natural water, the common range of pH falls within 6-8 (Lkr *et al.*, 2020; Thakre *et al.*, 2000). The Nsonji Lake has the significant range of pH indicating circum-neutral to slight acidic water (Table 1). The decline in pH may be attributed to the natural and anthropogenic acidification with the initial rise in the organic matter concentrations followed by its losses in the Nsonji Lake (Steinberg, 1991).

Alkalinity is not the same as pH and alkalinity was 50 mg/l during pre-monsoon season. Originally hardness is defined as a characteristic of natural water, contributed mainly by dissolved calcium and magnesium ions (Ikomi and Emuh, 2000). Hardness of pre-monsoon was 50 mg/l. Chloride is present in all types of natural water and in some cases its main contributing sources are runoff from inorganic fertilizers. The chloride content was found to be 30 mg/l during pre-monsoon and fall within the permissible limit of 1000 mg/l (BIS, 2012). Similarly for residual chlorine the concentration was 0.2 mg/l for pre-monsoon. Iron content was about 0.3 mg/l during pre-monsoon which is under suitable limit. Ammonia was 0.5 mg/l in pre monsoon season. Even in low concentration ammonia is toxic for aquatic lifeforms. Nitrite content is 0.2 mg/l during pre-monsoon season. Nitrate is usually the result of fertilizer runoff from farmland in surface waters, excessive nitrate can lead to eutrophication (WHO 1998) resulting in death of aquatic lifeforms and serious health hazards. The nitrate content was 45 mg/l in pre-monsoon. Total Dissolved Solid during the pre-monsoon was 156 mg/l. TDS measure was all under the permissible limit of 2000 mg/l (BIS, 2012). Various parameters for pre-monsoon are within the recommended ranges as per the guideline (BIS, 2012). The presence of finely suspended matter (Silt and clay) and microscopic organisms can elevate the turbidity to high especially during post monsoon (Gadhia *et al.,* 2012).

Table 1: Water quality analysis (Pre-monsoon) of Nsonji Lake (BDL: Below Detectable Limit)

Parameters	Pre-monsoon
Colour	Colourless
Turbidity	Low
pH	7
Alkalinity mg/l	50
Hardness mg/l	50
Chloride mg/l	30
Iron mg/l	0.3
Ammonia mg/l	0.5
Nitrite mg/l	0.2
Nitrate mg/l	45
Phosphate mg/l	BDL
Residual chlorine mg/l	0.2
Total dissolved solids mg/l	156

Diatom Analysis

Identification and enumeration of diatoms from the surface sediments of the Nsonji Lake was done through morphological examination of different species. The classification of diatoms is largely based on frustules form and sculpture (Mann, 1999). These preserved lake diatoms can be used to decipher paleoclimatic changes through water chemistry, temperature shifts and nutrient concentration. The present preliminary study has recorded the presence of total 71 species of diatoms belonging to 30 genera from the Nsonji Lake of the Nagaland. The following are the most abundant diatoms species present in the surface sediments of the Nsonji Lake: *Discostella stelligera, Achnanthidium* sp., *Navicula cryptocephala, Navicula radiosa* and *Nitzschia palea* (Fig. 2).

Discostella stelligera proliferates favorably in high temperature, more light availability under shallower mixing depth (Stoermer and Ladewski, 1976; Saros *et al.*, 2012). *D. stelligera* also commonly grow in the elevated nutrient levels, when surface layer lake is affected by light and temperature under shallower depth (Malik and Saros, 2016). *D. stelligera* blooms during spring (Boeff *et al.*, 2016) or autumn turnover (Koster and Pienitz., 2006). Lake's thermal structure can be influenced by factors such as changing water chemistry, turbidity *etc*, *i.e.*, factors related to climate and environment with enhanced nutrients, light and lake mixing are indicative of flourished *D. stelligera* (Saros *et al.*, 2012; Malik and Saros, 2016). Thus, the dominance of *D. stelligera* suggest that the Nsonji Lake has been experiencing high water temperature throughout the year under shallow depth and increased nutrient levels. *Achnanthidium sp.* is often reported from waters indicating acidic to alkaline condition (Novias *et al.*, 2015). *Achnanthidium sp.* species oftens shows dominance in flowing water, showing its growth in high velocity zones in streams and rivers and exerted anti-inference to wave zones lakes (Shen *et al.*, 2018). This species is the second highest in concentrations in the lake indicating the presence of well-oxygenated water. *Navicula cryptocephala* is widespread in waters indicating a moderate to high pH and high concentrations of nutrients (Lange-Bertalot, 2001). It is also present in the areas with higher deposition of sediments settling down in the bottom of lakes. Rani and Sivakumar, (2013) reported this species as indicator of organic pollution. *Navicula radiosa* thrives in lakes with abundant supply of nutrients (Hakkasson *et al.,* 1998). It exists in waters with high nutrient concentrations and able to reside in cloudy waters (turbid) and tolerates human activities (Lange- Bertalot, 2001). *Nitzschia palea* is one of the most tolerant and stress loving species known in this genus (Palmer, 1969). *Nitzschia palea* prefers to live in dominance in the lake with increased organic pollution (Venkatachalapathy *et al.,* 2014).

The circum-neutral water (*i.e.* pH: 7) of the Nsonji Lake very clearly manifest that the most dominant diatoms *D. stelligera* (~14.2%, centric), *Achnanthidium sp (~13.9%, Pennate) and Navicula crypocephala (~11.2%, Pennate)* prefer to live in the circum-neutral to slightly acidic waters under high water temperature, more light availability under shallower mixing depth. These diatoms can be very well used to understand the past acidification of lakes caused by natural or anthropogenic activities.

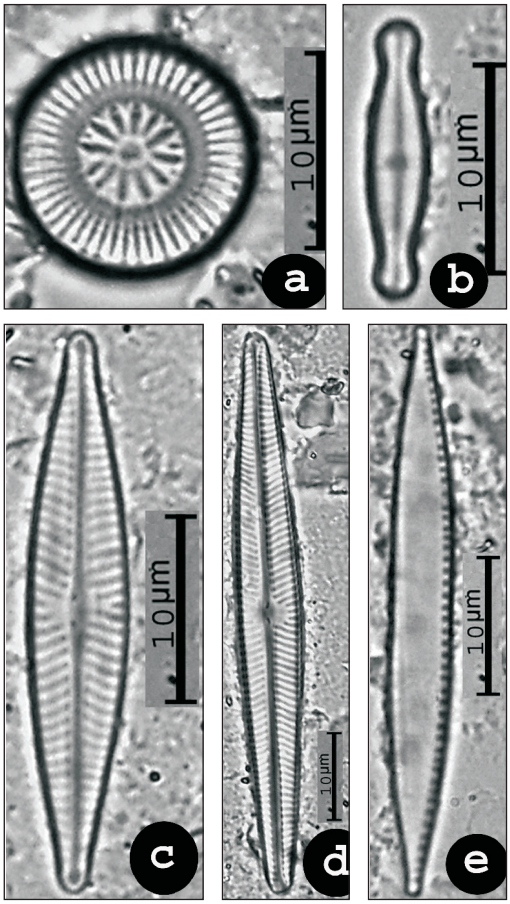

Fig.2. Dominant diatoms from surface sediments of Nsonji Lake, (a) *Discostella stelligera,* (b) *Achnanthidium* sp., (c) *Navicula cryptocephala,* (d) *Navicula radiosa,* (e) *Nitzschia palea*

Conclusions

Overall, the present study suggests a circum-neutral to slight acidic and mestrophic status of the Nsonji Lake during pre monsoon season. The hydrochemical analysis of water samples indicates a good quality of water having most of the parameters in normal range except circum-neutral pH. The Nsonji Lake has high diatom diversity with the maximum dominance of *Discostella stelligera, Achnanthidium* sp.*,* and *Navicula crypocephala*. These dominant diatoms thus corroborate the presence of shallow lake with increasing water temperature and moderate nutrient content. At present, the Nsonji Lake showing signatures of natural and anthropogenic acidification. However, further detailed investigations of the lake during pre and post monsoon seasons along with the sediment core study could help in understating the complete history of lake's acidification and based on that the appropriate mitigation measures could be taken up.

Authors' Contributions

ZK: Conceptualization, Formal Analysis Methodology, Investigation, Data Curation, Writing- Original Draft Preparation. **SSH:** Visualization, Writing- Original Draft Preparation, Writing-Reviewing and Editing, Supervision. **SMH:** Conceptualization, Writing- Reviewing and Editing, Supervision.

Conflict of Interest

Authors declare no competing of interests.

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