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Historical Review and Prospect on Diatoms study in India

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Abstract

In recent years, diatom studies have been consisting of different approach i.e., taxonomic study, contamination history, paleoclimate etc. The significant study has been reported from the different part of the Indian subcontinent. Especially in India, from the last several decades the study on diatom shifted from taxonomical classification to palaeothermometry study using isotopic analysis. To know the present status and get the future direction it is very important to review the past studies which not only gives the ample information about the records available but also benefitting to get future direction. In the present review we present the comprehensive review on records available from three different geopolitical regions. The review on these three regions shows that most of the work Indian parts in past decades diatom is mostly used for taxonomical and pollution study. However, baseline information on diatom diversity has not been examined in many Indian regions. In recent time the study has been shifted in the direction towards palaeothermometry reconstruction using advance analytical techniques such as stable isotope and others.

Keywords: *Diatoms, Himalaya, South India, Benthic Diatom, Unicellular*

INTRODUCTION

Diatoms are one of the prominent and ecologically most significant groups of organisms on the earth. Diatoms are unicellular, eukaryotic, photosynthesizing algae having siliceous skeleton and are found in all aquatic environments. Diatoms can be found in the oceans, freshwater, soils, and on damp surfaces. They live pelagically in open water, although some live as surface films at the water-sediment interface (Benthic) or even under moist atmospheric conditions. Moreover, there are diatom species that can live in either salt or brackish water, as well as some are common to brackish and fresh water, and a few can live either in the sea or in freshwater conditions.

Diatom's cell wall is made of Silicon dioxide (SiO_2), or glass frustules ranging in size between 20-200 microns in diameter or length, although sometimes they can be up to 2 millimeters long.

These frustules show a wide diversity in form but are usually almost bilaterally symmetrical, hence the group name. The symmetry is not perfect since one of the valves is slightly larger than the other allowing one valve to fit inside the edge of the other. The cell may be solitary or colonial. They are non-motile or capable of only limited movement along a substrate and play ecological roles in producing diatomaceous earth and toxic blooms in surface water. Diatoms are multiply rapidly, maintaining a dynamic population of varying sizes. Among unicellular microalgae, diatoms probably represent one of the most diverse groups with the number of species estimated to be between 10,000 to 100,000. Diatoms may occur in such large numbers and be well preserved enough to form sediments composed almost entirely of diatom frustules called as *diatomite* or *diatomaceous earth*. These deposits are of economic benefit being used in abrasives, filters, paints, toothpaste, and many other applications.

Diatoms are especially important in oceans, where they are estimated to contribute up to 45% of the total oceanic primary productions. They are at the beginning of a food chain which ultimately is a very major factor in the welfare of the human race. They are used as food by lower animal forms and crustaceans in the oceans which in turn support fish and other larger marine life. With improved techniques deducing sedimentation history of the lakes (Diwate et al., 2021) the diatom can be very significant as a prominent biological proxy for paleoclimatic study. In the present review we consider record from the three different parts of the country i.e., North India, Central India and South India (Fig. 1). All the previous study for the different defined parts of the country is reported in the present paper.

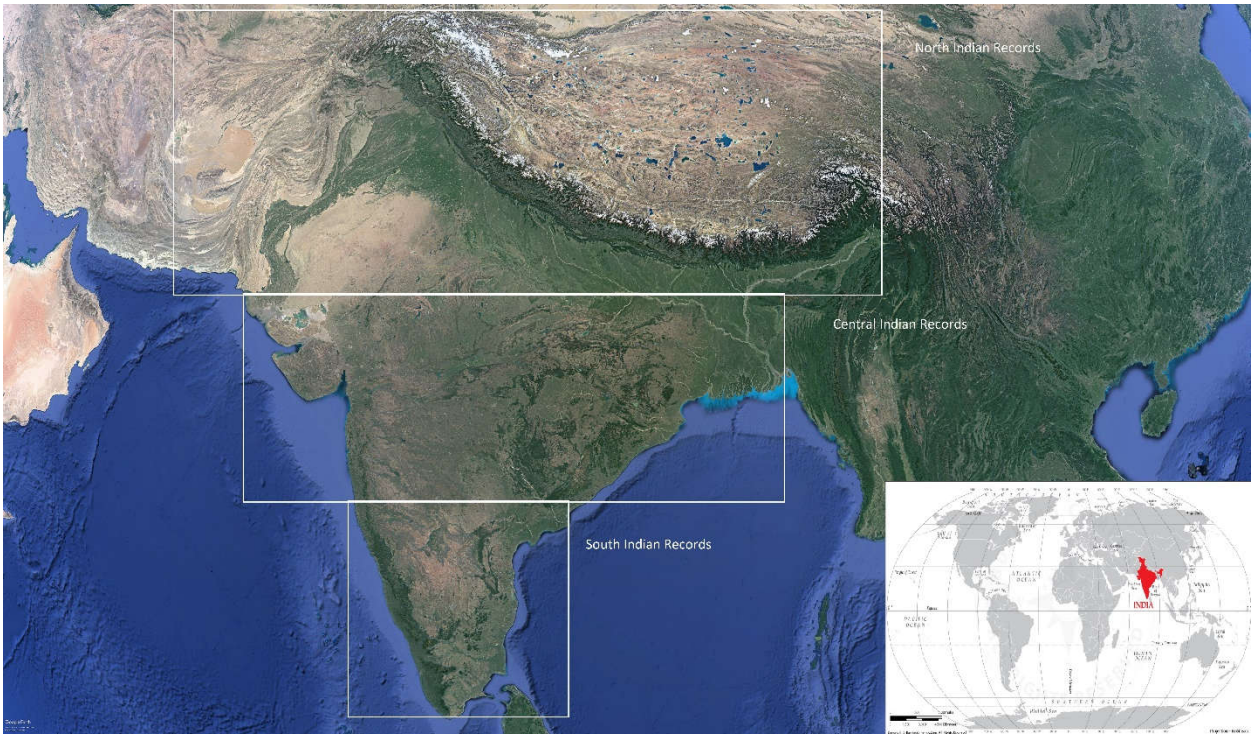

Figure 1: Study area map for the present study

RESULTS AND DISCUSSION

History of Diatom study

Historical Study of Diatoms in North India

Important investigations are made in Indian Lakes including those of Dakshini and Gupta (1984) on the ecological characteristic of three lakes in the union territory of Delhi as well as Singh and Rai (1984) on the ecology of Jabalpur Lake (Madhya Pradesh). Puttaiah and Somashekar (1985) studied the limnological aspect of Mysore city ponds and Kanungo et al. (1985) worked on the physico-chemical characteristic of some ponds of Raipur city. Puttaiah and Somashekar (1987) pointed out that higher carbon dioxide (CO_2) and lower concentrations of oxygen significantly contribute to the abundance of Euglenoids in the water bodies of Mysore city. Singh and Mahajani (1987) discussed the role of temperature, nitrate nitrogen, and phosphorus in phytoplankton variations in the lakes of Himachal Pradesh.

Zutshi and Khan (1988); Anand (1988); Bhattacharya (1988); Saifullah et al., (1988) who did considerable work on the chemical composition of standing water bodies concluded that both physical and chemical characteristic of water significantly affects the algal population, and they emphasized the importance of pH, total alkalinity, and carbon dioxide content of water on the succession of phytoplanktons leading to eutrophication.

The Himalayan region is geographically unique as well as physico-chemical heterogeneity with a major river system and is known as a biodiversity hotspot in the Indian sub-continent. But recently the ecosystem of the Himalaya is changing rapidly due to the pollution in the natural resources like streams, rivers, lakes, and sediments that affects the water quality (Singh et al., 1994). Therefore, to identify these problems we study the diatoms, which are very sensitive to environmental as well as hydrological changes. A few workers have studied diatoms from the Himalayas which were started in 19th century (Dickie, 1882). After that, the workers started their diatoms studies in the Himalayan rivers (Mandakini, Alaknanda, Ganga, Tons, Nayar, Godavary, Bhagirathi and Yamuna etc.), lakes and sediments to know about the diatoms biodiversity, taxonomy that linked to the water chemistry and environmental aspects (Dickie, 1882; Chakrabarty et al., 1959; Ray and Rao, 1964; Ray et al., 1966; Pahwa and Mehrotra, 1966; Nautiyal and Lal 1978, 1981; Singh et al., 1982; Nautiyal, 1984; Ormerod et al. 1994; Nautiyal et al., 1995, 1996a, b, 2019; Singh et al., 1994; Ormerod et al. 1994, Jüttner et al. 1996, 2000, 2003, 2010, 2012; Badoni et al., 1997; Rothfritz et al. 1997, Nautiyal and Nautiyal, 1996, 1999, 2002, 2018; Jüttner and Cox, 2001; Nautiyal, 2002, 2010; Ruhland et al., 2006; Nautiyal et al., 1997, 2004, 2007,2014, 2015; Bhatt et al., 2008; Nautiyal and Verma, 2009; Verma and Nautiyal, 2009; Bhakta et al., 2010; Pareek and Singh, 2011; Gurung et al., 2011; Nautiyal and Mishra, 2013; Dwivedi and Misra, 2015; Farooqui et al., 2015; Karthick et al., 2015; Roy and Keshri, 2016; Singh et al., 2017; Verma et al., 2017; Sharma et al., 2018; Roy et al., 2020; Phartiyal et al., 2021) and some other parts from the northern India (Majeed, 1935; Singh and Saha, 1982; Wojtal et al., 2010; Roy and Keshri, 2016; Saini et al., 2017).

Dickie (1882) was the first to observe 28 diatoms species from the Himalayan region. In Punjab, Majeed (1935) has done good work on diatom flora. Chakrabarty et al., (1959) found less diatoms density in the Yamuna River in the month of April whereas density is high in the Ganga River during the month of May. Kamat and Aggarwal (1975) reported diatoms from the Nainital, Uttarakhand. For the first time in Bihar, Singh and Saha (1982) was described 16 species belonging to 8 genera of the diatoms. Nautiyal (1984) studied the seasonal fluctuation of diatoms species along with physico-chemical parameters in the Alaknanda and Nayar rivers. Gandhi et al. (1986) reported the ecology of diatoms from the Karewa beds of the Baltal area, Kashmir, India. Nautiyal et al., (1995, 1996a, 1996b, 2019) reported 34 pennate diatoms taxa collected samples from April 1991 to March 1992 and the impact of sewage on 173 diatoms species in Alaknanda River (Srinagar Garhwal) and also reported 30 Araphid diatoms taxa having 5 genera from the Alaknanda River sampled during 1991-1992 (except monsoon season). Nautiyal and Nautiyal (1996, 1999,

2002, 2018) reported 29 diatom taxa in which 5 Raphidiod and 24 Monoraphid in the Alaknanda River during sampling 1991-1992, 194 diatom flora that found in Alaknanda-Ganga River during sampling 1991-1994 and 122 diatom taxa reported in during pre and post monsoon sampling in the Damodar River system. Nautiyal et al., (2004) reported 58 new diatom taxa, 32 from the Alaknanda and 26 from the Ganga River, and 200 diatoms taxa were found during 1999-2000 sampling at different altitude where 76 new diatom taxa were identified from the Mandakini basin. Nautiyal and Verma (2009) worked to know about the diatom diversity and identified 205 (42 genera) and 293 diatom taxa (49 genera) from the Yamuna and 108 diatom taxa (42 genera) from the Ganga River system from November 2003 to April 2004 sampling. Verma and Nautiyal (2009) reported 127 diatoms taxa from the Hiyunl Gad, Lesser Himalaya. Nautiyal (2010) reported 35 diatom taxa from Allahabad of which 13 were araphids, 16 biraphids, and 6 raphidiod diatom taxa. Wojtal et al. (2010) reported new diatom species *Achnanthidium Chitrakootense Spec. Nov.* from northern and central India. Pareek et al. (2011) sampled from the Galta Kund, Jaipur during October 2009 to September 2010 and studied 24 diatom taxa that show seasonal variation in growth. Nautiyal and Mishra (2013) reported 66 diatoms taxa from the spring-fed Khanda Gad used to know about the tropical status. Nautiyal et al. (2014, 2015) reported 193, 251, 130, 200, and 354 diatoms taxa from the Alaknanda River, Alaknanda-Ganga River system, Nagni Gad, Mandakini basin and the Doon valley respectively that shows the diversity in the species richness to evaluate the water quality, eutrophication status in the Himalayan rivers. Nautiyal (2014) reported 291 and 256 diatoms taxa from the Yamuna and Ganga drainage, Doon valley respectively. Roy and Keshri (2016) reported four taxa, namely, *Diatomamesodon, Fragilaria capucina var. vaucheriae, Punctastriata linearis and Ulnaria ulna* from Srikhola River, Eastern Himalaya, in which two new diatom taxa found i.e.,*Fragilaria capucina var. vaucheriae and Punctastriata linearis.* Saini et al. (2017) used five different geographical locations from Haryana for the study of forensic diatomology and reported 25 diatom genera. Singh et al. (2017) studied the diatoms taxa with reference to the five spring habitats from the Doon valley. Verma et al., (2017) reported 30 diatom taxa of which 19 and 7 new species were identified from the Vindhyan and Himalayan River, respectively. Roy et al. (2020) gave new diatom taxa namely *Encyonemakeshrii sp. Nov* that sampled from the Kolli Hills, Tamil Nadu, and the mountains from the Eastern Ghats. Phartiyal et al., (2021) reported diatoms taxonomy for the study of paleoclimate from Ladakh-Karakoram (Trans-Himalaya).

Historical Study of diatoms in Central India

Sreenivas and Rana (1994) studied the ecology and tropic status of the Gomti tank, Gujarat, pointing out that the tank was on the verge of attaining a eutrophic state. Ravikumar and Puttaiah (1996) studied the ecology of Hassan district lakes. Padhi (1995) studied the water chemistry and algal communities on the three freshwater ponds in and around Berhampur in Orissa and suggested the revival methods using algal communities as biological indicators. He recorded wide variations in pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved oxygen (DO), phosphate, and nitrates. The seasonal variations in physico-chemical parameters like dissolved oxygen, chlorides, salinity, and planktonic composition of Kurichi ponds were studied by Arivazhagan et al., (1997). Sarojini et al., (1997) have studied the pollution of water resources in the Kolleru area. Wani (1998) has investigated the seasonal dynamics of phytoplankton in a shallow Himalayan Lake.

The study of diatoms started from the 18th century. Early work focused on collecting material for taxonomic analysis but by the mid-19th century, a strong global perspective had already developed. In the 20th century, the use of diatoms in biostratigraphy, environmental change, and ecology and biogeography proliferated as diatom ultra-structures, life cycles, and systematics. Most recently, systematics and molecular genetics have sought to reveal diatom genealogy and to refine its taxonomy. Because of their intricate siliceous cell walls and their global distribution in aquatic and terrestrial environments, diatom has

attracted the interest of naturalists and researchers alike since the 18th century.

Diatom research in India has a long history and can be traced to the pioneering research work of Ehrenberg (1845). Some prominent works on diatom taxonomy include that of Gonzalves and Gandhi (1952, 1953, 1954); Krishnamurthy (1954); Sarode and Kamat (1980, 1983, 1984); Gandhi et al., (1983a, b, c, 1986); Trivedy (1982); Jakheretet al. (1990); Anand (1998); Dadheechet al., (2000); Singh et al., (2006, 2010); Kumar et al. (2008, 2009), Tarar and Bodhke (1998); Bhagat (2002); Mishra and Mishra (2002); Mishra (2006) and Patil and Kumawat (2007). Studies on the ecology and taxonomy of freshwater diatoms have been dismally neglected in India and many regions are yet to be studied for baseline information on diatom diversity (Karthick et al., 2013). However, phytoplankton ecology has received frequent attention (Sarma and Khan, 1991; Karthick et al., 2010). Gonzalves (1947) was the pioneering worker on diatoms from the Maharashtra State. Thomas and Gonzalves (1965) recorded 98 diatoms from the eight hot springs of Maharashtra. Sarode and Kamat (1978, 1980a, b, c, 1983a, b, c) gave a detailed description of 227 species of diatoms for the first time from the Vidarbha and Marathwada regions of the Maharashtra state. Nandkar et al., (1983) described diatoms from sewage and oxidation ponds of Nagpur. Barahate and Tarar (1981, 1983) have recorded a few diatoms from Khandesh (Now Jalgaon region of Maharashtra). Sarode and Kamat (1984) described freshwater diatoms of Maharashtra.

Humane et al., (2009, 2010a, b, 2012a, b, 2015a and 2015b) and Humane and Humane (2014, 2015a, b and c) have reported various diatom taxa from the different lakes of central India and analyzed their trophic status. Humane et al. (2010a) have studied the environmental implication of the sedimentary diatoms of the Vena River. Forty-two species of the genus *Caloneis, Neidium, Diploneis, Stauroneis, and Anomoeneis* were recorded in the North Maharashtra region studied by Mahajan (2012).

Historical Study of Diatoms in South India

In India, the pioneer work was done by Venkatraman (1939 and 1956) on diatoms. He gave a systematic account of south Indian Diatoms. Menon (1931) has referred a few forms of diatoms and Gopala Iyer and Sankara Menon (1936) have given a list of diatoms collected from Madras Coast and Venkataraman (1939) has given an account of common freshwater diatoms of South India. The only comprehensive work on Indian marine diatoms is that of Subrahmanian (1946) wherein he has given a systematic account of 171 forms. Gonzalves (1947) has recorded 126 species of diatoms from Bombay harbor. Gonzalves and Gandhi (1952, 1953, and 1954), Krishnamurthy (1954), and Gandhi (1955) reported on the freshwater diatoms collected from various parts of India. Prasad (1954) has given a list of diatoms occurring in the plankton in the Mandapam area, with special reference to seasonal variations. An account of marine diatoms from Indian waters was also given by Nair (1959) and Gopinathan (1975). Diatoms are readily observable in the light microscope and their occurrence was well known by the late 18th century (Round et al., 1990), but it was not until the 19th century that awareness of the large diversity of micro-organisms developed as microscopical techniques improved. In the past 150 years or so, diatom research has diversified into several major fields ranging from ecology and micropalaeontology to systematic and molecular genetics. Robust models are now available for reconstructing a variety of environmental changes, including pH (Birks et al., 1990), and salinity (Fritz et al., 1991). Recently, Roy et al. (2020) reported new diatom species in Kolli hills, Tamil Nadu. Venkatachalapathy et al., (2013, 2014) have investigated diatoms and water quality assessment of Yercaud Lake in Tamil Naidu. Logannathan et al., (2014) have studied the distribution of freshwater diatoms in the Perumal Lake, Tamil Naidu. The polluted and unpolluted zones of river Gomati using diatoms were demarcated by Verma et al., (1996, 2000).

Present Status and Prospects on Diatom Study in India

Recent research has attempted to evaluate processes like sediment transport and revealed information about estuarine hydrodynamics, the quality of the water (Liu et al.,2015), as well as environmental processes (Townend et al., 2011)

that can be linked directly to the movement of energy and suspended matter. Due to their sensitive nature and excellent preservation in lake sediments, diatoms can provide a continuous record of environmental history. Scientists use diatoms as potential bioindicators to monitor present and past environmental conditions across continents. Additionally, diatoms also prove to be an excellent indicator of acidic systems, where the occurrence of other bioindicators is limited. Diatoms have received a lot of attention because they produce a lot of lipids and biomass, which can be used in a variety of commercial applications like biofuels like biodiesel, and aviation fuel. By fixing CO_2 in the atmosphere, they help clean the environment and reduce greenhouse gas (GHG) emissions.

CONCLUSION

Present paper presents the comprehensive records from three different geopolitical region. The review on these three regions shows that most of the work in Indian parts in past decades on diatom is mostly used for taxonomical and pollution study. However, in recent time the study has been shifted in the direction towards palaeothermometry reconstruction using advance analytical techniques such as stable isotope and others. According to the publication, research on diatoms has significantly increased in recent decades. Numerous new diatom species and genera, particularly from the tropics, have been described in recent years. Numerous brand-new diatom species have been discovered through recent research. However, baseline information on diatom diversity has not been examined in many Indian regions. Scientists use diatoms as potential bioindicators to monitor present and past environmental conditions across continents

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