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A review on diatoms of freshwater bodies of Rajasthan

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Abstract
Diatoms are single-celled photosynthesising eukaryotic algae having great importance ecologically and forensically. They have a siliceous skeleton (frustule) and are found in almost every aquatic environment including fresh and marine water bodies. This review attempts to study the diatom ecology in the water bodies of Rajasthan. Diatoms are found in the body of the drowned individual and can be used as corroborative evidence in cases to answer the questions like the site of drowning, time of drowning, ante-mortem or post mortem drowning. It can also be served as reliable proof of site and time of drowning, even in the cases of contamination due to immersion of the body into the water for a longer time. This review study revealed that the most common diatoms reported in the waterbodies of Rajasthan belong to species Navicula, Nitzschia, Cyclotella, Synedra, Fragilaria, Gomphonema whereas some site specific diatom's species are also reported like Stauroneis in Kaylana lake of Jodhpur, Brachysira in Chambal river, Kota, Achnanthidium in Chambal river, Kota and Maavath pond (Jaigarh fort), Anomoeneis in Indira Gandhi Canal, Hanumangarh.

Keywords: Drowning, Post mortem, Diatoms, water Bodies,

1. INTRODUCTION

Rajasthan being the largest state by area (342,239km^2) of the Union territory of India, encounter more physical variations than any other state. It is situated between 27.0238° N latitude and 74.2179° E longitude.[1] It is one of the arid state with average rainfall less than 100 cm annually. Due to this scarcity of water, Rajasthan has a tradition of preservation and management of water resources and thus contains artificial lakes, dams, reservoirs, etc. It has both saline and freshwater lakes.

Diatoms are universal organisms that belong to the class Bacillariophyceae of division Chrysophyta and kingdom Protista. More than 200 genera of living diatoms are reported, and approximately 1,00,000 species are estimated.[2] Diatoms have the characteristic feature of secreting an external wall composed of silica known as Frustules.[3] They are autotrophic mostly (auto-self; trophic-mode of living or nourishment) but can be symbiotic and heterotrophic in some habitats. They reside solitary or maybe in a colony sometimes, live freely, or attached to a substratum. Diatoms have a very diverse role in ecology as they play an important role in Carbon and silicon cycles along with it also act as bio-indicators due to its specific narrow tolerance characteristics.[4] Some species of diatoms are restricted to only a specific habitats and they are know as endemic species such as Aulacoseira in Central Asia,[5] Stauroforma in saline water[6], cymbelloid diatoms in Asian freshwater bodies & Eunotoids in South America [7]

Diatoms have a very significant role in forensics in drowning cases. As the signs of anti-mortem drowning disappear very quickly, the diatom test helps in determining whether the drowning was anti-mortem or post-mortem.[8] Drowning can be defined as immersion in any liquid, enough to cause the death of an individual. According to a report, drowning is second most common cause of death accounting for total 9.4% of unnatural deaths after road accidents.[9] Drowning signs depend on the time-lapse after the drowning took place. Early signs include a large amount of froth in nostrils and mouth along with the upper and lower airways, washerwomen symptoms on the palm, and sole which disappears later on.[10] To establish that drowning is anti or post mortem, a diatoms test is done to establish a link between the diatoms found in the organ sample of the body due to inhalation of water during drowning, causing entry of diatoms in circulatory as well as respiratory system and the diatoms found in the water sample collected from the drowning site. Diatoms get deposited in sternum, femur, kidney, brain and other organs and therefore for investigation both hard bones and soft tissues are sent to forensic laboratories for diatom detection. [11]

Drowning death diagnosis is one of the major task of forensic pathologists to determine the cause of drowning deaths. Many methods have been developed by scientists for detection of diatoms in tissue samples. Hofmann first detected the diatoms in lung fluid[12] , in bone marrow by Tamaska[13] and, in blood and parenchymal organs by Incze. Timperman reported the presence of diatoms in lung,liver, spleen, kidney, brain tissue and bone marrow. Incze further demonstrated that diatoms could enter into lungs through circulation.[14] Timperman developed a qualitative and quantitative method of diatom tests for drowning death investigation[15] which was letter improved by Pollen's Acid digestion method.[16] In acid digestion method, 50 ml conc Nitric Acid(HNo_3)is added to the conical flask containing tissue sample and kept overnight. Next day, it is boiled for about 48 hour, which give a clear yellow colour solution with a fat layer on top. After discarding the top layer, the solution is centrifuged at 4000 rpm for 10 minutes and washed with double distilled water. Microscopic slides are prepared from the sediment and observed under phase contrast microscope.[17] This method has limitations of destroying structure of diatoms due to acid treatment, therefore other methods such as Lefort Aqua regia (3:1 Nitric acid :Hydrochloric acid) and reverse Lefort Aqua regia. However, diatom test as indication of drowning has still many limitations such as in some cases of non-drowned individuals diatom can be reported in which the individual consumed non-vegetarian food containing abundance of diatoms, inhaled in environment where paper, cement etc is manufactured etc.[18]
The first scientific record of Diatoms was published in the Royal Society of London in the Philosophical transactions in 1703 by an unknown scientist. On microscopic analysis, he reported that there is something which adhered to the roots of a plant weed and also free floating in water, which on later studies was found that it was filamentous diatoms of species Tribularia.[19] Kutzig in 1844, first classified diatoms as algae in his monograph of diatoms. Diatom's fossil records suggest that the first diatom were found in marine water which have radially symmetrical valves. The fresh water diatoms were not prevalent until the Coenozoic era and later on the pennate diatoms were reported in late Cretaceous period and Raphid in Paleocene. HP Gandhi was pioneer in diatomological studies and known as father of freshwater diatomology in India and his works date back to 1944 in the waterbodies of Bombay.[20]

Many works have been done on diatoms species over Rajasthan by different researchers and botanists. But very few findings are from a forensic significance point of view and more work is done as limnological and phytoplanktonic studies to assess the quality index of water and

for ecology studies. The very first attempt to study diatoms in Rajasthan was done by H.P. Gandhi (1955) in Pratapgarh district of Rajasthan where he reported species of Cyclotella, Synedra, Eunotia, Caloneis, Navicula, Pinnularia, Amphora, Neidium, Cymbella, Gomphonema, Nitzschia, Hantzschia & Surirella in the surrounding ditches and ponds of the town.[21] Later on, V. Khanna et al. (2009) reported species of Melosira, Nitzschia, Navicula & Surirella in the holy lake of Pushkar to study its planktonic diversity.[22] G.K. Barupal(2019) recently done his studies on freshwater bodies of the arid region of Rajasthan(Jaisalmer, Jodhpur, Bikaner & Churu) to study its algal biodiversity and concluded that Eunotia, Nitzschia, Rhopalodia, Hantzschia were dominant diatoms species there.[23] Rajvinder Singh et. al. (2006) done work on three major water bodies of Jaipur and reported that in Galta Ji which is flowing from one side to other have abundant diatoms of species Synedra & Melosira along with Rhoicosphenia & Cyclotella whereas in Jal Mahal's lake only Cyclotella were dominant because it is highly polluted and is stagnant. Mavaath is a seasonal pond and contains a large diversity of diatoms like Navicula, Geisselaria, Achnanthidium, Nitzschia, etc.[24] A collective work on 10 ponds of Churu was done by G.K.Barupal et al. (2018**)** in which they reported species of Amphora, Navicula, Gyrosigma, Diadesmis, Gomphonema, Cymbella, Achanthes, Cocconies, Fragilaria, Synedra, Ctenophora, Nitzschia & Cyclotella.[25] On river Chambal the work has been done two different times by Meera Bhatnagar et al. (2013) [26] and Sarika Grover et. al. (2017) and they both reported the species of Navicula, Cyclotella, Cymbella, Rhopalodia, Melosira & Gomphonema. More species were reported by Sarika Grover et. al. like Achnanthidium, Cocconeis, Caloneis, Amphora, Nitzschia, Brachysira, Neidium, Sellaphora & Hantzschia.[27]

The general species observed are Navicula, Nitzschia, Synedra, Gomphonema, Fragilaria & Cyclotella. Brachysira is the species of diatom of order Navicules which is specific to Chambal river only [27] whereas Navicula is the species present in abundant in every water bodies except Kunda reservoir of Bharatpur and the reservoirs of the arid region of Rajasthan(Jaisalmer, Jodhpur, Churu & Bikaner).Species of Achnanthidium is only limited to the Chambal river of Kota[27] and Maavath of Jaipur. Stauronies are the diatoms found in Northern rocks and are found where the pH is around acid to circumneutral and in Rajasthan, they are found specifically in lentic Kaylana lake of Jodhpur (Prakash Narayan and G. K. Barupal, 2015) [28]. Indira Gandhi Canal reported Anomoeneis which is not found anywhere else till now in any water bodies.[4] It usually grow in brackish water indicating that this canal has salinity more than freshwater but not more than sea.

CITY	**NAME OF WATER BODY**	**SPECIES FOUND**	**AUTHOR & YEAR**
Pratapgarh	Pools and ditches surrounding the town	Cyclotella, Synedra, Eunotia, Caloneis, Navicula, Pinnularia, Amphora, Neidium, Cymbella, Gomphonema, Nitzschia, Hantzschia, Surirella	Gandhi H.P.,1955 [21]
JAIPUR	Galta Ji (Reservoir)	Melosira, Synedra, Rhoicosphenia, Cyclotella, Navicula	Singh, et al., 2006 [24]
	Jal Mahal	Cyclotella, Navicula	
	Mavaath(Jaigarh	Nitzschia, Diatoma,	

	fort)	Navicula, Geissleria, Achnanthidium, Cyclotella	
KOTA	Kishore Sagar	Cyclotella, Chaetorus, Melosira, Amphora, Caloneis,Cocconeis, Cymbella, Diatoma, Fragilaria, Gomphonema, Gomphonesis, Nitzschia, Navicula, Neidium, Syndera, Surirella	Narayan et al., 2008 [29]
PUSHKAR	Pushkar Lake	Melosira, Nitzschia, Navicula, Surirella	Khanna et al., 2009 [22]
JAIPUR	Mansagar Lake(Jal Mahal)	Navicula, Gomphonema, Synedra, Melosira, Nitzschia , Coscinodiscus , Cyclotella	Singh et al., 2010 [30]
JAIPUR	Galta Kund	Cyclotella, Melosira , Navicula, Achnanthes , Amphora , Synedra, Nitzschia , Gomphonema Hantzschia Pinnularia and Fragillaria	Pareek et al., 2011[31]
JAIPUR	Maotha Lake	Navicula, Gomphonema , Nitzschia , Synedra , Melosira ,Coscinodiscus , Fragillaria	Singh et al., 2011[32]
UDAIPUR	Pichola lake	Cyclotella, Synedra, Fragillaria, Nitzschia, Arerionella, Amphora, Gomphonema, Cymbella, Bacillaria,	Sharma et al., 2011[33]
KOTA	Chambal river	Amnoseia, Cyclotella, Cymbella tumbida, Fragilaria sp., Gomphonema, Melosira sp. , Navicula Nitzschia, Pinnularia, Rhopalodia, Synedra ulna, S. gracilis	Meera Bhatnagar et al., 2013 [26]
UDAIPUR	Jaisamand lake	Synedra, Rhopalodia, Gyrosigma, Pinnularia, Neidium, Gomphonema, Cymbella, Diatoma, Navicula, Cyclotella, Fragilaria, Melosira, Surirella	Vijay Kumar et al. (2015) [34]

Sri Ganganagar	Gang Canal	Nitzschia, Achanthes, Fragilaria, Navicula Cymbella, Gomphonema, Cocconeis	RK Bishnoi et al. (2015) [35]
Bharatpur	Kunda reservoir (open pond)	Synedrafasculata, Cyclotellacomta, Cyclotellakutzingiana, Stephanodiscushantzschii, Suireriatenera, Tabellaria sp.	Sunder Singh (2015) [36]
Jodhpur	Kaylana Lake	Amphora, Navicula , Diadesmus , Gyrosigma , Stauronies , Gomphonema , Cymbella , Eunotia , Fragilaria, Synendra, Ctenophora, Nitzschia , Achnanthes, Cocconies, Cyclotella	Prakash Narayan et al. ,2015 [28]
Hanumangarh	Indira Gandhi Canal (Ghaggar river)	Cyclotella, Melosira, Coscinodiscus, Stephaniodiscus, Fragilaria, Synedra, Navicula, Anomoeneis, Meridion, Gyrosigma, Gomphonema, Cymbella, Nitzschia, Meridion	Manoj Kumaret al., 2017[4]
Kota	Chambal River	Cyclostephanos, Cyclotella, Melosira, Achnanthidium, Cymbella, Cocconeis, Caloneis, Amphora, Nitzschia, Gomphonema, Rhopalodia, Brachysira, Navicula, Neidium, Sellaphora, Hantzschia	Grover et al. ,2017 [27]
Churu	10 ponds(Fatehpuria pond, Sethani Johada, Pithana Johada, Droun pond, Manaksar pond, Natho pond, Talchhapar pond, Chadwas Pond, Parmana pond, Girdhar pond)	Amphora, Navicula, Gyrosigma, Diadesmis, Gomphonema, Cymbella, Achanthes, Cocconies, Fragilaria, Synedra, Ctenophora, Nitzschia, Cyclotella,	Barupal.and Meghwal ,2018 [25]
The arid region of Rajasthan(Jaisalmer, Jodhpur, Bikaner &	Water tracts of Jaisalmer, Jodhpur, Bikaner	Eunotia, Nitzschia, Rhopalodia, Hantzschia	Barupal ,2019 [23]

Churu)	& Churu		
Sawai Madhopur	Chambal river	Synedra, Eunotia, Cocconeis, Achanthes	Lakhpat, 2020 [37]

2. CONCLUSION

Diatoms play a very major role in the investigation of drowning cases in determining the mode and cause of death. It also help in linking to the site of drowning as well as in determining that whether the drowning was anti-mortem or post-mortem. A study of diatoms of waterbodies with its seasonal variations will help in mapping of diatoms containing information of its location and sampling site. Diatomological mapping will help the forensic pathologists in generating the data for investigation of drowning deaths and locating the site of drowning as well as assessing the quality index of water. Many ponds, lakes, and rivers which are major tourist spots of Rajasthan are still not studied and they are more prone to accidental drowning as well as homicidal, therefore more studies can be done in near future for diatomological mapping.

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