

A Review on Diatom Mapping In India: Forensic Identification of Diatoms Based on Morphology

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ABSTRACT

Diatoms are categorized as phytoplankton's which are found in water. There are greater than two hundred genera of living diatoms which are estimated and around 100,000 species exist. There are 9 morphologies of diatoms namely, symmetrical biraphid, centric, eunotoid, asymmetrical biraphid, epithemoid, surirelloid, araphid, monoraphid and nitzschoid,. The most recurrent use of diatoms in forensic science in the case of death due to drowning as well as linking the victim with the crime scene. Since the type of diatoms and assemblage number varies from ecosystem to ecosystem, it is therefore important to have data on type, assemblage of data of the area for the forensic use. This study introduces about the basic of the subject explaining various sub-disciplines & reviews the study conducted on different water bodies across India.

Keywords: Diatoms, Morphology, drowning, Forensic Science.

INTRODUCTION

Diatoms are found in nearly each oceanic environment counting fresh waters and marine waters, in truth nearly anyplace sodden locale. They are classified as unicellular, photosynthesizing algae. They may be simple or branched, filamentous, and indeed encompassed in a thick envelope or tube [4].Diatoms exhibits four main features such as- silicified cell wall, box like structure, secondary structure or marking on the cell wall and photosynthetic pigments i.e. chlorophyll A and chlorophyll C, Xanthophyll and Fucozanthin.

The cell wall of diatoms is called as frustules which is made up of silica and consists of 2 valves linked by a connective zone called a girdle. Size of diatoms varies from approx. 5 -1000 microns. Diatoms belong to a group called heterokants, which includes heterotrophs and Autotrophs. Reproduction in diatoms is by two ways-Asexual reproduction and Sexual reproduction.

They are by and large non-motile, or have restricted mobility by discharge of mucilaginous matter from a slit-like groove or channel called a raphe. The raphe is the structure that provides motility to diatoms. Raphe position may be (1) axial, along the apical axis; (2) eccentric, around periphery of either valve; or (3) circumferential, around the periphery of whole valve.[6,33]

There are greater than two hundred genera of living diatoms which are estimated and around 100,000 species have been discovered.[6] There are 9 morphologies of diatoms, namely centric, epitheimioid, symmetrical biraphid, asymmetrical nitzschioid, biraphid, eunotioid, monoraphid, araphid and surirelloid.[14]

Diatoms classification:

Classification of Diatoms are based on saline, life form, trophic, pH preference and habitat

- Diatoms classification based on their salinity tolerance spectrum were categorized as Polyhalobous, Mesohalobous and Oligohalobous.

Polyhalobous species grows in marine conditions, which has a salt concentration more than thirty practical salinity units (psu). Mesohalobous diatoms grow in the range of 0.2-30 psu of salt concentration. Oligohalobous diatoms happen in salt concentrations less than 0.2 psu. **Hustedt (1953, 1957,2006)**

- Sub category of Oligohalobous is Oligohalobous-halophilus, Oligohalobous-indifferent and Oligohalobous-Halophobous

Oligohalobous-halophilus, which have a most favorable condition in feebly brackish waters, Oligohalobous-indifferent that majorly occurs in fresh water, but also shows resistance for little brackish conditions. Oligohalobous-Halophobous diatoms are found exclusively in fresh water and they are highly intolerant in salt water. Vos and de Wolf (1993, 2006) and Juggins (1992, 2006)

- Diatoms classification based on the life form i.e-

Euplanktonic diatom species- this species has a planktonic habitat, i.e. they live only there and also reproduction and metabolism takes place within the water itself. Tychoplanktonic

diatoms-they take place in the plankton habitat, but primarily they occurred in supplementary habitat. Epontic diatom species- majorly live by attached to other substrata and they are sessile. Benthic diatom species- not attached to substrata but live in the sediment. Denys (1992, 2006)

- Diatoms classification based on optimum pH-

Alkalibiontic diatoms- found in water whose pH level is more than 7. Alkaliphilous diatoms- occur in water where pH is about 7 and more than pH. Circumneutral diatoms- this species occur at pH 7 and less than pH 7. Acidophilous diatoms- occur at pH 7 but majorly found at pH below than 7. Acidobiontic diatoms- this species occur at pH value below 7 but the most favorable condition where they found are at pH 5.5. Hudstedt(1937-39, 2006)

Reproduction in diatoms

Diatoms are known as unicellular organisms. The cell components of diatoms are chromatoplasts, vacuoles, cytoplasm, and nucleus. Silica wall is present in diatoms which is porous which helps in exchange of gases and passage for nutrients within the cell. They are divided into two groups pinnate and centric. The centric are round in shape and pinnate are elongated.

Reproduction in diatoms is by two ways-

1. Asexual reproduction

It is the primary appearance and binary fission is the technique through which asexual reproduction takes place. Asexual division in diatoms is the ordinary method of reproduction (Bold 1978). This vegetative cell division includes lessening in cell size, as the daughter cells are produced by replication of DNA which causes the chromosome to divide into two identical halves, due to which two frustules or theca are formed. Each daughter cell acquires one of the parent cell's frustules, which creates small frustules (hypotheca) to form a larger frustule (epitheca).so as parent cell grow larger which helps in dividing into two daughter cells by pushing out of the valve. Each daughter cell has a new cell wall. Shrinkage in the size of cell takes place. In diatoms the shrinking division is the unique mode of asexual reproduction.

2. Sexual reproduction

It is firmly combined with cell size of diatoms. When the cell size decreases than a particular level then this method triggers itself. Pennate and centric diatoms possess different sexual reproduction process.

In centric diatoms, sexual reproduction is oogamous. A male gamete undergo in division where it forms a number of sperm mother cells or microspores. After that sperm mother cells

undergo meiosis to shape into flagellated sperm. The oogonial female cells generate eggs which can be 1 or 2, sperm entry facilitates by the female protoplast due to which fertilization takes place. Zygote is thus formed.

In pennate diatoms, sexual reproduction is isogamous which means the egg and sperm gametes are indistinguishable. Gametangial cell join together and undergo meiosis.

New diatoms will increase in volume while forming vegetative cells and solid silica shells (Alexopoulos, 1967).

Use of Diatoms in Drowning Cases

Drowning is defined as respiratory impairment from being in or under a liquid.

When a body is found in water bodies, it is considered to be doubtful case whether death was occurred due to drowning or it was a post-mortem submersion. In ante-mortem drowning case diatoms will enter into the lungs and then carried to other parts of the body e.g.kidneys, brain, and bone marrow by circulation whereas in the case of post-mortem drowning, as there is no circulation,thus the movement of diatoms to body organs is barred and thus in no case diatom getsaccess into the body. Thus diatoms are supposed to be diagnosed from the internal organs of the body as only in ante-mortem drowning, and it should be considered as the positive result of anti-mortem immersion. After diagnosis, the diatoms which were found in the body are compared with the diatoms of the drowning medium (water body) where body was found.[9]

Application of Diatoms in Forensic Science

Diatoms, in algal community are especially useful in crime scene to link the suspects and victims to crime scenes in the region of fresh water.[5] Diatom species are effectively distinguished from the characteristic shape of the cells and special refractive design caused by the silica within the cell wall.[10]Seasonal and geological variety in diatom plenitude and differing qualities is utilized to create botanical profiles of aquatic environments which can at that point be compared

to specimens collected from body tissues or other materials recovered from the scene of crime.[3] Diatom tests are routinely used for the analysis of drowning cases [9], and in evaluating the autopsy interim, or time since death .[4]

In drowning cases, recovered bodies from the water are investigated as important part of the medico-legal examination. Drowning cases are not easy to solve as the minor signs in drowning are not specific and putrefaction also vanishes them. Chemical and biological marker of drowning are not accepted as scientific evidence but the diatom analysis are done as this maintains a standard but it is rather labor intensive.[10]

Diatoms in lungs were first time discovered by Holfmann (1896) [10]. Peabody (1977) considered diatoms as the important forensic evidence in drowning cases. [20]

Death due to drowning is diagnosed by diatom test. This is a most reliable test in the absence of other evidence.[3,20,23]

Natasha and Aleksej(2009) resolved 29 drowning cases and increased the value of diatom test to conclude the manner of death.[18]

Drowning is an essential aspect established in the forensic diatomology application. Some workers contributed to this timid field. [15,21,31]

DIATOM MAPPING OF INDIA

In India, a study on diatom flora of Ahmadabad lakes Chandola and Kankaria has been done in 1964. This study concluded that different factors affect the presence of diatoms like climatic, biotic and edaphic factors. It was also found that diatoms are cosmopolitan types and few are

specific. 23 diatoms were recorded from the study & they are from 10 diverse genera. Of these, six are new records for India and three species and one assortment is considered to be new.[7]

A study of diatoms of three water bodies Galta ji, Jall mahal, Mavath of Jaipur has been conducted in 2006 and concluded that number of diatoms vary from one site to another under the same climatic conditions. [27]

Diversity of diatoms in the Jayakwadi Bird Sanctuary has been examined from the year 2005 to 2008 and their ordered accounts have been stated. Diatom genera of Navicula, Caloneis and Gyrosigma were found at different areas of sanctuary.[1]

A study mentioned the importance of diatom in drowning cases investigation in Punjab 2009. The Practical and theoretical concept of Diatom Mapping was reported in that study. The data of Diatoms has been produced from the examination of 10 different water bodies in Punjab during different season's i.e winter ,summer, autumn, spring.[30]

Diversity of freshwater diatoms in the Galta kund, Jaipur has been examined from the year 2009 to 2010. 24 species of diatoms were recognized from Galta Kund. These species have a place to 11 genera specifically: Synedra (2), Cyclotella (2), Gomphonema (3), Navicula (4), Nitzschia (5), Achnanthes (2), Melosira (2), Hantzschia (1), Pinnularia (1) , Amphora (1) and Fragillaria (1).[19]

A study was conducted to determine the diatom distribution pattern in a changing physicochemical environment in the Mahi River Basin, western India. Results showed the dominance of bottom-dwelling pennate shapes of diatoms above floating centric forms of surface waters, which otherwise prefer pond water, suggesting control of physicochemical conditions,

which further is a function of local lithology. The lower region of the Mahi Basin that are dominated with industrial effluents show higher frequency of *Cymbella* spp. and *Synedra capitata* suggesting slightly increased eutrophic conditions.[2]

Diatom species abundance for seven lakes of Mysore were studied from 2008-2010 and fifty five diatom species were recorded. Diatoms in the hierarchical range were *Gomphonema sumatranse*, *Gomphonema baltonis*, *Gyrosigma kuetzingii*, *Nitzschia viridula*, *Gomphonema subapiculatum* and *Navicula gracilis*. [11]

Asystematic study at Junnar Tehsil of Pune District (Maharashtra) in 2012 has concluded the presence of 155 diatoms. It consist 25 genus representing 82 species, 60 varieties and 13 forms. All these taxa are new records from this region. *Navicula*, *Gomphonema* and *Cynella* are more densely occur in Junnar Tehsil.[28]

Diatom mapping has been done in water bodies of Haryana in 2013 to distinguish commonly found and seasonal diatoms. A total of one hundred and eleven species and their fifty five genera of diatoms were distinguished. Diatom genera which were common at all the 10 locales were *Aulacoseira*, *Asterionella*, *Cyclotella*, *Navicula*, *Synedra*, *Tabularia*, *Gomphonema*, *Achnanthes* and *Nitzschia*. The diatoms that were found to be location specific are *Opephora*, *Cymatopleura*, *Cyclotella* and *Capartogramma*. *Eunocymbellarania vandana*, a new genus of diatom was discovered, thus it make it location specific.[34]

Diatoms arrays dispersion in Cauvery Rivers, Bhavani, Tamil Nadu, India(2013) in connection to chemical and physiographical variables. About 37 diatom species disseminated among 17 genera were recorded. Profoundly contaminated water contain diatom species like *Nitzschia thermalis*, *Pleurosigma salinarum*, *Gomphonema lanceolatum*, *Gomphonema parvulum*,

Fragilaria intermedia and marginally contaminated water display the diatom species like Cymbella tumida , Cyclotella catenata and Achnanthes minutissima Kutz.[32]

A study "Seasonal variations and diversity of marine diatoms of Jegathapattinam (Lat. 09° 95 N: Long. 79° 18'E) Kattumavadi (Lat. 10° 13'N; Long. 79° 22'E), Sethubhavachathiram (Lat. 10° 24' N: 79° 28'E) and Manora (Lat. 10° 26' N; Long. 79° 30'E) of Pudukkottai and Thanjavur District, South east Coast of India was carried out for a period of one year (from June 2010 to May 2011). For this study, four stations were chosen from the both districts. During the study period, an overall 78 species belonging to 42 genera of marine diatoms were recorded from the four stations. The most common genera were *Actinocyclus*, *Amphora*, *Bacteriastrum*, *Biddulphia*, *Chaetoceros*, *Coscinodiscus*, *Cyclotella*, *Diploneis*, *Gyrosigma*, *Licmophora*, *Mastogloia*, *Melosira*, *Navicula*, *Nitzschia*, *Pleurosigma* and *Tropidoneis* were present in all the stations. Higher values of diatom population density were found during summer at both stations. [8]

A study has been carried out to discover diverse sorts of diatoms in 24 water bodies in Haryana amid Jan-March 2015. About 39 morphologically diverse diatoms were found which incorporate 6 new sorts that were not reported earlier. Around 60% of add up to diatom composition contained Navicula, Cymbella, Neidium sorts and as it were around 2% were Hantzschia, Eunotia, Surirella types.[24]

27 water samples were collected from different 9 sites of Gomati River at Jaunpur District in the months of December, January and February in 2016. The collected water samples were extracted for identification of diatoms after acid digestion and their slides were made, according to the arrangement of valve and cell wall shape. On the basis of these examinations, 36 genera

identified from different nine sites. Out of 36 genera, 18 genera were found at (Sooraj Ghat), 17 genera Ram Ghat, 13 genera (Achala Devi Ghat), 10 genera (Viserjan Ghat), 17 genera (shiv Gopal Ghat), 14 genera (Hanuman Ghat) , 11 genera (Kirarbeer Ghat), 10 genera (Balua Ghat), and 8 genera (Gular Ghat) . In which 15 diatom genera were identified common at all sites . 7 specific diatom genera were identified on specific site.[17]

10 waterbodies of Mumbai, Maharashtra, India 2016

10 water bodies of Mumbai, Maharashtra, India, were examined for Diatom mapping in the year 2016 & 35 diatom species beneath 17 genera were distinguished .The chosen water bodies are as takes after: Valkeshwar (Balganga), Bandra(Swami Vivekanadare Talav), Borivali (Meethi Nadi), Navi Mumbai(Palm Shoreline),Kalyan(Durgadi, Kala Talav, Umberdenadi), Chembur(Ganesh Talav) and Thane (Brahmala Lake, Talav Pali) . The genera of species of diatoms that have been recognized are: Gyrosigma,Eunotia,Navicula,Nitzschia,Surirella, Melosira,Hantzschia,Frustulia, Pinnularia, Fragilaria, Gomphonema, Cyclotella,Cymbella, Neidium, Synedra, Caloneis and Epithemia.[22]

In Mizoram state, Three rivers of common drowning sites were selected for the Diatomological study in 2016. Since all the samples were collected from running water bodies (rivers) during the winter season, the environment and the climatic conditions were not favorable for the growth of diatoms. 21 diatoms were identified up-to their genera level. Though all the samples had been collected in the same season (i.e. winter) with not much difference in the temperature and the pH (all the rivers were slightly alkaline), but still diversity was observed from river to river and from different sites of the same river (i.e middle and bank).[26]

In Gujarat, biological variation of marine diatoms along coastal waters at Veraval & Saurashtra coast was carried out from May 2012 to April 2013. Around 133 species of Diatoms were discovered. The frequently found diatoms throughout the study were: *Coscinodiscus asteromphais*, *Odontella mobiliensis*, *C. subtilis*, *C. oculus iridis*, *O. rhombus*, *Thalassiothrix frauenfeldii*, *Rhabdonema* sp., *Nitzschia lanceolata*, *Melosira molyniformis*, *Grammatophora marina*, *P. normanii*, *Navicula longa*, *N. seriata*, *Navicula* sp., *Licmophora abbreviata* and *Pleurosigma aestuarii* .[29]

In Renuka lake of Himachal Pradesh ,the Diatomological study were carried out in 2018,The water samples were collected during the all four seasons of India. All the samples were extracted by using acid digestion method and analyzed by using light microscopy. The result of the present study suggested that there were significant variations observed in the diatomological composition among all the seasons.[13]

The diatom profile of Bhakra Canal close to Narwana, Haryana, India have been examined. The diatoms were distinguished by utilizing both light and checking electron magnifying lens. A add up to of 13 genera & 24 species of diatoms were found & among them *Navicula*, *Synedra* and *Nitzschia* were the common-most .*Cymbella*, *Aulacoseira* and *Cocconeis* were recognized seasonally, whereas *Achnanthes* and *Rhoicosphenia* were found to be site-specific diatoms.[15]

Eight water bodies of Himachal Pradesh 2019

Diatomological study of 8 waterbodies of Himachal Pradesh across *Una*, *Bilaspur*, *Mandi*, *Kullu*, *Sirmaur* and *Kinnuar* districts were carried out during all the seasons using SEM.[12]

SUMMARY & DISCUSSION:

Diatoms are having different and unique pattern of microstructure and symmetry. Reproduction in diatoms is by two ways-Asexual reproduction and Sexual reproduction. Classification of Diatoms is based on saline, life form, trophic, pH preference and habitat. the diatoms which were found in the body are compared with the diatoms of the drowning medium (water body) where body was found. In ante-mortem drowning case diatoms will enter into the lungs and then carried to other parts of the body whereas in the case of post-mortem drowning, as there is no circulation, thus the movement of diatoms to body organs is barred and thus in no case diatom gets access into the body.

This study has reviewed the studies related to Diatom mapping within India. 19 studies reveals the Diatom data of 10 states.

Table 1: Diatom mapping of India

Author	Year of publication	Place in India	No of Diatoms
Gandhi, H. P	1964	Chandola and Kankaria, Ahmedabad, Gujarat	23 Diatom types/10 Genera
Singh et al.	2006	Galta ji, Jall mahal, Mavath of Jaipur, Rajasthan	9 Diatom Genera
Andhale, S. B et al.	2009	Jayakwadi Bird Sanctuary, Paithan, Maharashtra	3 Diatom Genera
Thakar, M. K., & Singh, R.	2010	10 Water bodies of Punjab	51 Diatom Genus
Pareek, R., & Singh, R.	2011	Galta kund, Jaipur, Rajasthan	11 Diatom Genera
Anupam, S et al	2011	mahi river basin in western India	-
Hosmani, S. P.	2011	seven lakes of Mysore, Karnataka	6 Diatom types

Tagad, R. N	2012	Junnar Tehsil of Pune District (Maharashtra).	25 Diatom Genus
Vinayak, V et al	2013	Haryana	55 Diatom Genera
Venkatachalapathy, R., & Karthikeyan, P.	2013	Cauvery Rivers, Bhavani, Tamil Nadu	17 Diatom Genera
Gopalakrishnan, T., Jeyachandran, S., & Ramakrishnan, N.	2014	Pudukkottai and Thanjavur District, South east Coast of India	42 Diatom genera
Saini, P., & Kushwaha, K. P. S.	2016	24 water bodies in Haryana	39 Diatom types
Mishra, S.	2016	9 sites of Gomati River at Jaunpur District ,UP	36 Diatom genera
Rana, D., & Bhandari, D.	2016	10 water bodies of Mumbai, Maharashtra	17 diatoms Types
Singh, R., & Zolawmsangi, J. O.	2016	three rivers of Mizoram	21 diatoms Types
Temkar, G. S et al	2018	coastal waters at	133 Diatoms species

		Veraval,Gujarat	
Kaur, A et al	2018	Renuka lake in Himachal Pradesh	-
Luthra, D et al	2019	Bhakra Canal near Narwana, Haryana	13 genera
Kaur, A., & Singh	2019	eight water bodies of Himachal Pradesh	-

These data could be used for reference to solve criminal cases related drowning i.e to distinguish between post-mortem & ante mortem drowning. It has been concluded that there is a dire need to conduct diatom study throughout the country to get a full fledged system of Diatom mapping & these details could be entered in a software or site that can be used by forensic expert for reference in solving the drowning cases.

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