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Forensic Diatomological Mapping: A Data Base for Diatom Profiling to Solve Drowning Cases

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ABSTRACT

Drowning data from past years shown a large number of people pass away accidentally in rivers, ponds, lakes and oceans. A Forensic expert can locate the probable or putative site of drowning by considering the *diatom test.* The present review focused on the investigation of drowning death is an essential aspect for the law enforcement agencies. However, a limited or little knowledge of forensic experts in the field of diatomology can hamper diatom related analytical strategies. Review implicate the progress and generation of *Diatomological mapping* of water bodies to make more conversant the scientists, researchers and other academician dealing with the investigation of drowning cases.

Key Words: Drowning, Diatom test, Diatomological mapping

INTRODUCTION

Drowning is the occurrence of respiratory impairment when air is prevented from entering into the lungs due to submersion/immersion of mouth and nostrils into water or other types of the fluid medium. Drowning generally occurs in accidental or suicidal cases, and sometimes also in homicidal post-mortem drowning. It becomes very important for law enforcement agencies to confirm whether drowning was the actual cause of death or not. The death occurring due to drowning is called antemortem drowning whilst the death occurred before entering into the water or body is dumped after homicide by any mean termed as post-mortem drowning.

International status of drowning incidents

A report covering twelve years (1988-2000) data revealed that 50 children younger than 5 years drowned in private swimming pools in the western part of Australia.[1] A review on epidemiological studies on locations and circumstances surrounding drowning deaths concluded that most of these studies were limited to a particular single country. Only two studies presented some comparative international database and one study examined global drowning mortality devoid of country-wise age-specific drowning mortality rate.[2] Some earlier studies on drowning related the age, race, disease, alcohol and other factors with drowning incidents.[3] The foremost Global Burden of Disease (GBD) study conducted in the 1990s by the World Health Organization (WHO) and the World Bank demonstrated that drowning is one of the most common causes of death throughout the world and reported 5,04,000 deaths due to drowning.[4] GBD in another study revealed that global drowning mortality was around 6.8 per 100,000 persons affecting all age groups. Low to middle-income countries indicate around 98.1% human deaths with drowning.[5] A global research data produced by GBD revealed that unintentional drowning stands 21st on ranks out of 179 causes of death. Interestingly, it ranked 12th in Eastern and Central Asia and 54th in Western Europe.[6] A report revealed a detailed picture of drowning mortality rates among children in low income and middle-income countries in Asia.[7] In a report, the WHOmentioneddrowning a serious and neglected public health threat as around 3,72,000 lives are lost every year.[8] A huge survey on deaths due to unintentional drowning in different ages and body of water analyzed from 60 countries by WHO. A significant disparity in age-standardized mortality rate (deaths per 1,00,000

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population) revealed 0.12 in Turkey and 9.19 in Guyana. Major findings revealed the highest age-standardized mortality rate in countries like Lithuania, Belarus, Latvia, Russia, Moldova, Ukraine, Kazakhstan and Kyrgyzstan. The proportion involving bathtub drowning was huge in Japan followed by Canada and the United States of America.[9] A recent study also supported drowning as a leading killer throughout the world.[10] A population-based retrospective study from 2008 to 2012 based on drowning from Canada was conducted to uncover the characteristics of drowning incidents in context to age groups. Age-specific frequencies revealed varied death rates (per 100,000) in different age groups. The age group from 5-14 years produced only 0.57 death rate while the highest value (1.74) was calculated in the age group 65 years and above. There was a significant gender-based difference standing with the male vs. female ration being 5:1. The study was suggested helpfully for drowning prevention strategies.[11]

Status of drowning cases in India

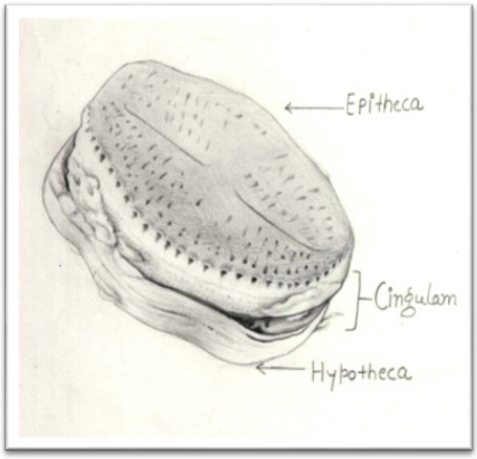
Drowning responsible as one of the most common unnatural causes of death in India. An 11 years (1994 to 2005) retrospective study derived profile of drowning victims to identify the successful drowning preventive measures to adopt or enhance in Mangalore city of south India.[12] A data revealing 536 cases of death due to drowning happened during 2005-06 was reported from Punjab.[13] The survey made by the National Crime Record Bureau (NCRB) during 2013 in India, explored around 8.0% deaths due to drowning out of all accidental and suicidal deaths. It was observed that on average 82 persons die due to drowning every day in India.[14] It was observed that 73.9% of the cases died due to accidental drowning while suicidal and homicidal cases were 16.1% and 0.1% respectively. A report from Lancet in December 2019, there were 62,000 drowning deaths in India in year 2017.[15] A recent data of Accidental Deaths and Suicides in India (ADSI) published by NCRB around 29696 drowning incidence and total 30,187 deaths in the year 2018 was occurred due to drowning.[16]

FORENSIC ASPECTS OF *DIATOMOLOGICAL MAPPING* AND DROWNING

Investigation of drowning death is an essential aspect for law enforcement agencies. The statistics from India have also pointed drowning as one of the commonest modes of committing suicide.[17-20] Establishing the exact cause of death has been considered a very difficult task for the experts due to few vague autopsy findings and in most of the cases and the controversial appreciation of the laboratory investigations by the scientific community.[21-23] Here, *Diatomological Mapping* plays a significant role in answering drowning related queries particularly when the putative site of drowning is required to be known. Use of *Diatom test* in establishing antemortem drowning was revealed by Peabody in 1977 in England. Last few decades have seen advancement in diatomological studies in forensic science. It started in 1996 byLudes and associates in France and still working. Therefore, this review article would provide the progress of D-mapping in forensic diatomology which would be helpful for health, academic and research field.

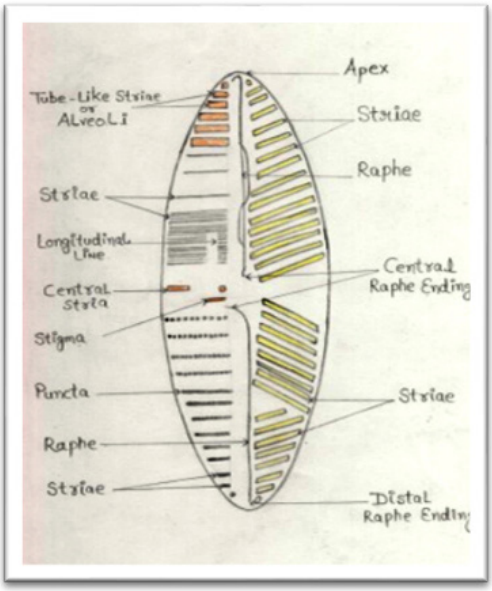
Forensic Diatomology

Forensic diatomology is defined as the application of diatoms for solving drowning related cases for medico-legal purposes.[13] In1878, the diatoms were first seen in the lungs.[24] Later, the diatoms were thoroughly studied and applied to establish ante-mortem drowning.[25] that gave way to *'Diatom test'*. Since then there has been a use of forensic diatomology. The '*Diatom test'* is a reliable method to determine the cause of death due to drowning based on diatomological interpretations about quantitative and qualitative analysis in the human body and reference water sample was used as an indicator of antemortem drowning.[26-29] Diatoms are microscopic unicellular algae belong to class 'Bacillariophyceae' and grouped under planktonic algae. They are photosynthetic having the unique structure of siliceous double shells. Status revealed that there are over 350 living and 150 extinct diatom genera wrapping around 12,000 living and 5000 extinct species.[30,31] Diatoms may occur in circular, oval, triangular or modified square shapes and varies from micron meters (µm) to millimetres (mm) in size. Based on symmetry, diatoms are classified into two categories. Central are basically of radial symmetry and striations are present concerning a CenterPoint while Pennalesare generally 'boat-shaped' though maybe un-boat shaped distinctively having the striations concerning the central line. Two frustules *i.e.*epitheca (outer) and hypotheca (inner) are like small boxes with lids, one half of the shell fitting inside the other (Figure 1). Most of the diatoms are observed under the compound light microscope as availability of an electron microscope is very limited in the country. Enhance magnification in Scanning electron microscopy helpful in the study of each feature in detail and confirmed the species of diatom (Figure 2). They are found in colonies or filaments, usually yellow to light brown, and are dispersed in fresh and marine aqueous habitats. They are sensitive to changing water quality, geographical parameters and act as an excellent environmental indicator as they can grow at different levels of temperature, pH, and salinity of the water. These parameters may affect the diatom population and concentration in water bodies.[28,32,33]



(1a)

Figure 1a: Showing the frustule of Pennales diatom.



(1b)

Figure 1b: Important morphological details of diatom symmetries.

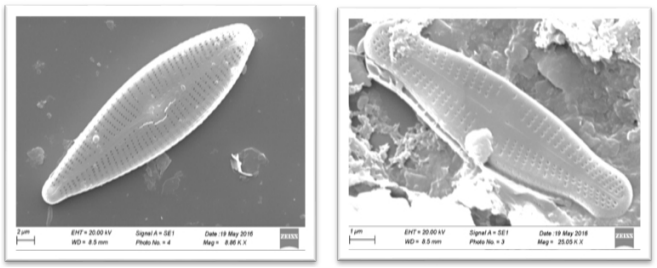


Figure 2: Some diatom genera images under the Scanning electron microscope.

The entry of diatoms in blood and bones

Breathing underwater during antemortem drowning draws a lot of water in the lung cavities that exerts high pressure on walls of lungs. Heavy impact ruptures these alveoli networking in lungs and pushes the water deep into the blood circulation. As long heartbeats, the water keeps on mixing with the blood and also pulls diatoms present in the water medium towards various vital organs such as spleen, brain, liver, kidneys and bone marrow. In case of post-mortem drowning where breath has already ceased before entering the water, the diatoms can be detected up to the lungs due to the passive absorption of water but they remain unreachable to distant body organs due to lack of respiratory thrust (Figure 3). There are also some other types of antemortem drowning where diatoms may not enter the blood circulation or lung cavities even. They are classified as *Laryngeal spasm* and *glottis spasm* (dry drowning). '*laryngeal spasm*' which prevents the flooding of lungs with water**.** This is also called as '*dry drowning'* where the victims die due to fatal cerebral hypoxia caused by 'suffocation' (asphyxiation). The reverse is true with '*wet drowning*' where freshwater enters the lungs and instant and massive absorption of this fluid takes places into the circulation across the alveolar-capillary membrane.

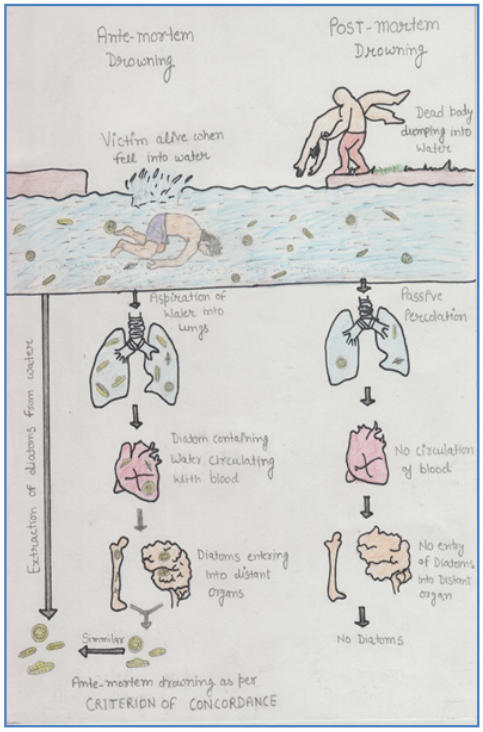


Figure 3: Diagramaticaly represent the Fate of diatoms inside the body in antemortem and post-mortem drowning.

The authenticity of *Diatom test*

While many of peer-reviewed research papers and articles have been published on the potential of *Diatom testing* for

the diagnosis of drowning but its reliability remains little controversial.[34,35] Contamination of the samples, passive absorption of diatom containing water, absence of diatoms in antemortem drowning, and false-positive results where the diatoms are found in non-drowned bodies target the reliability of *Diatom test*. Despite being surrounded by these controversies, the *'Diatom test'* has remained applicable in many countries for establishing antemortem drowning. Literature also supports that duly controlled *Diatom test*ing is an applicable way of confirming drowning as the cause of death.[36,28] It is the *criterion of concordance'* that verifies the validity of the *Diatom test.*[37] According to this criterion, the significant number of diatoms should be present inside the distant vital organs and they should match with the diatom species found in the body of water from where the body has been recovered**.** On the other hand, in absence of reference water samples requirement of the definite minimum number of diatoms in different vital organs of a drowned person can also establish antemortem drowning. This criterion proposes positive '*Diatom test*' only if there are more than 20 diatom frustules per 100 ml of the residue obtained by enzymatic digestion from 10 g of lung tissue and more than 5 diatom frustules per 10 g of sediment from other internal organs *i.e.* liver, brain, kidney and bone marrow.[27]

Diatomological Mappingas index of drowning location

It makes the investigation more tedious when the reference water body is not available or body has dragged or floated away from the actual site of drowning.[29]For this situation a scientific method is significant to locate the most putative site of drowning. This method is supported by using the forensic characterization of water bodies by using the practice of '*continuous monitoring'*[38]and'*Diatomological Mapping'*s the method to record the profiles of diatom flora of any water body species in different seasons.[29] Literature reports the role of *Diatomological Mapping* in answering drowning related queries particularly when the putative site of drowning is required to be known. These studies are based on qualitative and quantitative analysis of commonly occurring, site-specific and rarely occurring diatoms concerning usual seasonal and geographical changes at water body site.[29,39] This involves species level profiling of diatoms from water bodies and their comparison with diatoms found in the drowned body can provide strong evidence for determining the site of drowning.[38,40-42] Forensic application of differential distribution of diatoms flora has also been discussed in past by the Indian experts.[43,44]

It is also important to note that the habitat-specific property of diatom species may help the experts to use them in identifying the putative location of drowning.[35] Depending on their nutrient and light requirements, the qualitative and quantitative measure of diatom can vary in water bodies, even water running parallel. The development and growth of diatoms are sensitive to changes in water pH[45-48] and temperature.[49]

Forensic diatomological databasing of water bodies (*Diatomological Mapping*)

Generation of diatomological profile provides support to inclusive diatom comparison from both, the site and body. The study of diatom flora in a freshwater lake of *Hussain Sagar* area[43] and different water bodies, especially lakes and ponds of Delhi (India) was done in different seasons[44] concluded the qualitatively and quantitatively variation in diatoms at different locations and this observation might be significant for investigation of drowning cases. Another major contribution in diatomological studies for forensic applications was reported from three main water bodies of the Strasbourg (France). It was named a *'river monitoring programme/system'*. Collection of water samples at a monthly interval from two canals and one river highly involved in drowning incidents. The occurrence of diatom flora differed with month and site and later compared with the diatoms recovered from biological mater after autopsying 30 drowned bodies. The qualitative observations in these cases showed positive *taxa* connection with the flora of the known site of drowning. It was observed that diatom profiles of these rivers appeared specific under the circumstance where five most frequent genera, period (month) of sampling and pollution linkage (if any) were considered as markers of a particular site of drowning.[38] In support to this effort, another study compared two different series of cases involving 20 cases accidental or suicidal drowning with known drowning site and 20 another corpses where the drowning site was unknown. Earlier establish diatomological profiles were taken for comparison in the second case where information about the exact site of drowning was unavailable. The concordance of diatom in the assumed drowning medium and lung samples were 70%, but almost 100% match was observed where drowning site was truly acknowledged. It was proposed that the concordance diatom distribution in the lungs and reference water might be an interesting method of choice in support to locate the site of drowning.[50] Validity of *Diatom test* was refined and tested after analysis of fifty-two cases of drowning from Lake Ontario in Canada. Useful information about diatoms and their relationship with temporal and regional variation came to notice from the same body of water. It was found that findings were important enough for corroborating evidence for strengthening *Diatom test.*[51]Sediment particles from Dona Paula (Goa, India) during April and May showed diatoms belonging to genera *Navicula, Nitzschia, Pleurosigma, Licmophora*and*Surirella*etc and it was found that nutrient concentration played an important role in the occurrence of diatoms.[52]Another study on diatomological analysis in support to locate the site of drowning conducted in Yoronjima (Japan) proposed that diatom population may vary concerning location, depth and distance of

shore.[40] A four years (1994-98) seasonal study investigated the 137 diatom species within 41 genera diatoms from three small shallow Karstic lakes (ModroOko, Desne, and Kuti) of Croatia, the genera of diatoms in highest number were *Surirella, Navicula*, and *Cymbella*.[53] A study based on the assessment of 29 drowning cases autopsied at the Institute of Forensic Medicine and Criminalistics in Skopje, the Republic of Macedonia during 1997-2002 described the criteria for differential determination of the manner of fatality of dead bodies recovered from water bodies. The findings of this study directed the usefulness of the *Diatom test* for forensic pathology about the medico-legal investigation of drowning.[54] A concise but significant diatomological monitoring of JalMahal (Lake), Mavaath (small pond in front of Jaigarh fort), and Galtaji (a religious water bath) of Jaipur, Rajasthan was conducted in July (summer) in 2005. Seasonal variations were significantly observed and concluded the species of *Melosira, Synedra, Cyclotella, Navicula, Nitzschia, Diatoma, Navicula, Geissleria, Rhoicosphenia* and *Achnanthidium*. Some site-restricted diatoms were observed in these water bodies but the study lacked the extensive work out.[55] By using a quantitative diatom based method two high profile cases were investigated. The focus was to confirm death due to drowning and to know the site of drowning. Both these methods revealed a strong statistically similarity between diatoms recovered from the lungs and clothing samples with the control samples from the water habitats.[35] The work of Gandhi, a pioneer Indian diatomist also called as the father of Indian freshwater diatom science dealt with diatom taxonomy of both freshwater and saline water about its application as bioindicator. He discovered nearly 299 new diatom species.[56] A further study from ten water bodies of Punjab (India) were thoroughly monitored for diatomological profiling during summer, autumn, winter and spring seasons during 2005-2007. Morphological analysis revealed 126 *texa* of diatoms majority belonged to order '*Pennales'*. The data of this study was utilized to generate '*diatomological maps'*. Qualitative and quantitative categorization depicted commonly occurring seasonal, rare, and site-specific diatom species. The diatomologists observed a significant diatom distribution in the selected water bodies.[29] Water samples collected from eight water bodies especially lakes and S*arovars* (religious water baths) of some districts of Haryana were screened for diatomological analysis and noticeable changes in the occurrence of diatoms were observed during the winter season.[57] The electron microscopic analysis of water bodies of Sakhalin Island revealed several diatom species of 19 genera of class *Centrophyceae.* There was also first complete data on the taxonomical range of Centrophyceae in Lake Sladkoye, lakes of Mount Spamberg, and the Tym river of Sakhalin Island.[33] Five lakes from the Yangtze River was worked out for diatomological inspection in June 2012.Two seasonal (Summer and winter) and site variation illustrate the distribution of diatoms in Pearl-River, Guangzhou were *Melosira, Synedra, Cyclotella, Actin-ocyclus, Navicula, Nitzs- chiaGomphonemaceae, Achnanthidium, Coscinodiscus, Cymbella, Pinnularia, Thalassiosira, Etmotia*etc. Among all these diatoms *Melosira* and *Cyclotella* were the dominant genra with variation in size. The study specifies that the number of diatoms was more in September (summer) than was in December (winter). Also, The Yangtze River in Hubei Province were compared at different sites only in one season. However, some of the diatoms observed in Pearl River were also found in Yangtze River in Hubei but both rivers were differentiated based on the dominant genus of the diatom.[58] A new species of diatom was discovered *Eunocymbellaraniavandana*, from the pond of Haryana.[59] Two year seasonal survey of some water-bodies located at different areas of Haryana was conducted to generate diatom profiles. A total of 111 species and 55 genera including commonly, least commonly found and seasonal diatoms were identified. This screening was named a '*Diatom fingerprinting'*.[60] Another study from five lakes from the Yangtze river was worked out for diatomological inspection in June 2012. Observed Diatom was identified by using scanning electron microscopy (SEM) which revealed genera like *Achnanthes, Cocconeis, Coscinodiscus, Cyclotella, Cymbella, Diploneis, Eunotia, Fragilaria, Gomphonema, Gomphonemaceae, Gyrosigma, Melosira, Navicula, Nitschia*, *Stephanodisus, Surirella, Synedra* and *Thalassiosira*in the both water-bodies. Findings of this study advocated location of drowning-site and the necessity to develop diatomological database for the future forensic strategies for diagnosing various drowning mysteries.[61]Four water bodies (Sukhna Lake Chandigarh, Kanjli Wetland, Kapurthala, Sutlej Water Body, Ropar and Guru Nanak Dev Thermal Plant, Bathinda) out of ten water bodies which were earlier studied by Singh *et al*., 2010revised after the gap period of four years to authenticating the *Diatomological Mapping*.The findings proved the reappearance of diatoms in different water bodies and the remarkable correlation of revised study observations with the previous database of the same water bodies was seen. Therefore, the surveillance of this study encouraged *Diatomological Mapping* of water bodies for applying in forensic science.[39] From the 15 sites of Chuanyang River of Pudong in September 2012, 12 diatoms species were observed.[62] There were 22 diatom species were identified from five different water bodies of Meghalaya. Observations showed that *Navicula* and *Gomphonema* species were the common genera followed by *Cymbella andNitszchia*.[63]Various studies conducted on distribution and characterizations of diatoms in different water bodies of China were evaluated, and a conclusion on the current situation and the limitations of the previous studies was drawn. It was found necessary to generate *Diatomological Mapping* program nationwide in a systematic way.[64] Twenty four small and large water bodies of Haryana were sampled in January to March 2015 for diatom analysis. A large database was generated which included 39 *genera* of diatoms.[65]Another study of *Braham Sarovar* located in Ku-

rukshetra, Haryana from November 2014 to June 2015 identified the various diatom species including *Cyclotella, Cymbella, Frustulia, Melosira, Achanthes, Brachysira, Navicula, Synedra, Tabularia*and *Rhoicosphenia*.[66] For the purpose of forensic diatomological analysis, ten different sites of the great river *'Ganga'* passing at Varanasi and Allahabad (Uttar Pradesh), India were sampled continuously in four months (January, February, March and April)in the year 2016 and total 22 diatom *genera* were identified, out of which species of *Actinocyclus*and*Triblionella* were specific diatoms of Varanasi while *Cyclotella* was characteristic to Allahabad.[67] Water samples of ten water bodies located in different parts of Mumbai (India) were studied for diatomological investigation. A total 35 species of diatoms including *Gyrosigma, Navicula, Surirella, Hantzschia, Melosira, Pinnularia, Eunotia, Fragilaria, Cymbella, Cyclotella, Neidim, Nitzschia, Gomphonema, Caloneis, Frustulia* and *Synedra, Epithemia*were identified in all water bodies.[68] Water samples were collected from five water sites (Lake, canal, well and pond) on a seasonal basis, winter (December), spring (March), summer (June) and autumn (September) from the different geographical area of Haryana, India (Himalaya foothill, plain area and Aravali hills). Scanning electron microscopy of observed diatoms was revealed the significant difference in diatom distribution as the environmental condition varies in these selected sites.[69]

The total 22 taxa of diatoms were identified through all the seasons in Renukalake, located in Sirmaur, Himachal Pradesh. The changes in temperature, pH, organic matter, nutrients, etc. were the reason for variation in diatoms distribution. According to study the majority of diatoms were observed in the bank region of the lake as compared to mid-region, also revealed the distribution of *Navicula* and *Cocconeis* as commonly occurring diatoms and *Pseudostaurosira*, *Puntastriata* and *Stauroneis* as rare diatoms. The comparison record of diatom distribution according to the season was shown in table 4.[70] A *Diatomological Mapping* of some water bodies of Madhya Pradesh, India has revealed the most commonly found diatoms were (*Navicula* and *Nitzschia*) found in almost every water body with variation in their quantity.[71] In Forensic study of Bhakhra canal in Narwana, Haryana the occurrence of site-specific diatoms aids the investigation of the suspected site of drowning. The study revealed the 13 genera and 24 species where *Nitzschia, Naviculla* and *Synedra* were found to be commonly occurring diatom species, *Cymbella, Cocconeis* and *Aulacoseira* were identified as seasonally occurring diatoms, while *Rhoicosphenia*, and *Achnanthes* were site-specific diatoms.[72] The *Diatomological Mapping* of Chongqing section of the Yangtze River and Jialing River (China) recognized some site-specific and seasonal diatoms which can be proved significant for the investigation of seasons or specific sites of drowning. The data of diatoms was studied and recorded by using a Microwave Digestion-Vacuum Filtration-Scanning Electron Microscopy (MD-VF-SEM) method.[73]

The approach towards diatomological research in Forensic Science laboratory (FSL), India

The FSLs have always made efforts in research for solving the drowning cases. After a medico-legal examination, the crime exhibits are sent to the laboratory along with the samples of water from which the dead body is recovered. Research papers from Forensic science laboratory (FSL) MadhubanKarnal, Indiadifferentiate the antemortem and post mortem drowning by using *Diatom test.*[74-76] Drowning data and diatom diversity were also published by FSL, Jhunga, Himachal Pradesh, India so that it can be significant for the record and future perspective. Also, this study revealed that mostly accidental drowning occurred in the rainy season; however, more attention and safety programs should be adopted in this particular season to avoid these incidents. Advancement in the digestion of diatom from body organs was done from FSL Dharmashala, Himachal Pradesh, India. According to scientists, this method would be supportive in the detection of diatom and preparation of report within a few hours.[77]A case from Panaji, Goa, *Diatom test* report of viscera of a priest revealed that all the diatoms from viscera were identical to the water samples where the dead body has found.[78]Another case from the headless dead body from Amona, Goa in October 2018 was investigated for the suspected drowning. The *Diatom test* report of body organs samples confirmed the death was occurred due to drowning.[79] So, *Diatom test* has a vital role in ruling out the foul play in suspected death.

Merits and demerits of D-Mapping

Diatomological Mapping concludes both quality and quantity of diatoms in water samples which is supportive in the identification of putative drowning site, also maintain the record of water quality and environmental factors like salinity, temperature, pH etc. *Diatom test*is significance not only in the investigation of human drowning, but also in the diagnosis of veterinary drowning.[80] As mentioned in the literature, any fluctuation in the diatom growth factors brings notable changes in characterizations, distribution, quality and quantity of diatoms flora. Therefore, these changes can alter the data of D-mapping. For the perfect execution of D-mapping of water bodies, it is recommended that monitoring of diatoms and various related factors in water bodies should be done thoroughly on regular basis.

PERSPECTIVES

The problem of drowning seeks national and international attention to producing data at true scales, For this reason, it was thought that *Diatomological Mapping* will monitor the diatom flora concerning environmental factor provide the

immense help to the forensic scientist as well as pathologists in the investigation of drowning cases. It is recommended that the development of a worldwide comprehensive approach is needed to conduct prospect epidemiological studies to solve drowning related problem. It will lead to a better understanding of the burden of drowning and its key determinants. The authentication checking of four water bodies after the lapse of four years (2007-2011) observed the same diatoms which were identified in the earlier study and other few significant findings focused the use of diatomological maps for the characterization of water bodies in the future to solve drowning cases. Therefore, time to time monitoring of water bodies is necessary for the updating of *Diatomological Mapping*.[39] Distribution of diatoms in water bodies of different geographical localities were effected by some physical and environmental parameters. The locality with low temperature, less salinity and less polluted water had less quantity of diatoms.[69]Diatomological profiling is significant in observing similarities and differences in diatoms flora. So while preparing D mapping it is also necessary to record all parameters. Sometimes, the diatoms are not in intact form due to contamination, delay in diatom analysis and many other reasons. Therefore, morphological identification could not be done effectively. In those cases, some sensitive techniques like molecular investigation, Automatic Diatom Identification and Classification (ADIAC), Nuclear Magnetic Resonance (NMR) must be adopted. So, the analysis can be done effectively.[81,82] For the better outcomes of results water quality monitoring in all season and proper methodology for the collection of water sample would be programmed efficiently. *Diatomological Mapping* a new tool in forensic biology as well as in Forensic Medicine it must be constructed as organized research database.

CONCLUSION

The role and applications of forensic diatomology were well defined for determining the site of drowning. Seasonal and other various environmental factors such as pH, temperature, salinity are the governing factors of diatom distributions in any water body. Studies compiling a review of drowning cases and exploiting diatomology are not limited to forensic science but it is also an important asset for the other scientific field like medico-legal studies, botany, environmental sciences, and earth sciences. It will also provide beneficial lead to forensic investigators for future expansion.

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