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Review Article

ON THE IMPORTANCE OF DIATOMS AS ECOLOGICAL INDICATORS IN RIVER ECOSYSTEMS: A REVIEW

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ABSTRACT
Ecological indicators have widespread appeal to scientists, environmental managers, and the general public at large. They have long been used to detect changes in nature, but the scientific maturation in indicator development has occurred mainly in the past twenty years. Currently, indicators are primarily used to assess the condition of the environment, as early-warning signals of ecological problems and as barometers for trends in ecological resources. The diatoms (Bacillariophyceae) comprise a ubiquitous, highly successful and distinctive group of unicellular algae which have served as the most valuable indicator for the ecological assessment of rivers round the globe for the past fifty years. The European Water Framework Directive has required them to be used for assessing the ecological quality of water resources since the year 2000. Diatoms are highly sensitive to changes in nutrient concentration, organic pollution and aquatic productivity. This paper attempts to focus on the rationale for the use of diatoms as bio monitors. It incorporates various diatom indices developed for the eco-assessment of rivers from various regions of the world. In India, many research papers have been published with respect to bio monitoring by plankton and macro invertebrates, yet the diatoms have been rarely used for bio assessment of major rivers.

Keywords: *Bacillariophyceae, Biomonitors, Diatom Indices, Eco-Assessment, River Ecosystems*

INTRODUCTION
The rapid increase in anthropogenic activities threatens the sustainability of services provided by ecosystems Millennium Ecosystem Assessment, (2005), and some of the planetary boundaries for sustainable use have already been exceeded (Rockstrom *et al.,* 2009). Rivers are a paradigmatic example of this situation: they provide key services to society, harbour a large part of the world biodiversity, but are amongst the most endangered ecosystems of the world (Hering *et al.,* 2006; UNEP, 2007; Elosegi & Sabater, 2013). All around the world there are urgent demands for comprehensive methodological approaches to evaluate the actual state of these ecosystems and to monitor their rate of changes (Li *et al.,* 2010).

So far as the health of rivers in India is concerned, river pollution has now reached to a point of crisis due to geometric increase in human population coupled with rapid urbanization, industrialization and agricultural developments (Trivedi *et al.,* 2008). The situation warrants immediate reprisal through radically improved water resources and water quality management strategies. The Water (Prevention and control of pollution) Act, 1974 emphasizes on the wholesomeness of the water bodies and under its sections stresses on protection of human health and living creatures. Similarly the recently notified Environmental Policy, 2006 (MoEF, 2006) also strongly emphasizes on protection of wildlife, fisheries and other living beings.

Bio Monitoring: An Appealing Tool for Water Quality Assessment
Water quality evaluation based on physical, chemical and bacteriological measurements commonly form the basis of monitoring as they have been known to provide a complete spectrum of information for proper water management (Li *et al.,* 2010).

However, physical and chemical methods restrain the assessment of water conditions to that particular moment when the measurements are taken and thus, do not provide an integrated reflection of the water quality. In addition, even continuous chemical monitoring and data logging can miss events that might seriously impact key members of biological communities. It is also difficult to predict the interactive or synergistic influences of combinations of chemicals on aquatic biota.

Moreover, increase in the diversity of pollutants in aquatic bodies has augmented the complexity in water quality monitoring and management strategies, rendering the assessment of every potential pollutant, impractical. Thus, monitoring aquatic ecosystems by biological communities becomes indispensible.

To quote Lowe & Pan (1996) "Life is the ultimate monitor for environmental quality" and aquatic communities are the first elements to be disturbed by modifications in physical or chemical quality of rivers.

For more than a century (Stevenson & Pan, 1999), many concepts and tools based on biological aquatic organisms were developed in various countries for water quality assessment and are used by the water managers (Rimet *et al.*, 2005). The European Union Water Framework Directive (EC Parliament and Council, 2000), has made the biological monitoring mandatory for the assessment of the quality of surface waters.

In fact, bio monitoring has been proven to be a necessary supplement to all traditional monitoring techniques (Soininen & Könönen, 2004). It reflects overall water quality, integrating the effects of different stress factors over a passage of time. It gives a direct measure of the ecological impact of environmental parameters on the aquatic organisms and provides a rapid, reliable and relatively inexpensive way to record environmental conditions across a number of sites (Bellinger & Sigee, 2010). Pollution events or levels not detected by infrequent chemical data collection can be captured by biological monitoring. Biological indicators, therefore, are important for identifying problems otherwise missed or underestimated by chemical monitoring, and they constitute a class of response indicators closest in hierarchy to the desired outcomes related to ecological health of water bodies (Karr & Yoder, 2004).

Rivers: The Highly Variable and Dynamic Ecosystems

Rivers and streams are dynamic ecosystems which exhibit high spatial and temporal variations. To evaluate the actual state of these ecosystems and to monitor their rate of changes is a challenging task. The shortcomings of conventional analytical approaches are more explicit in running waters, where changes in hydrology are rapid and difficult to estimate and hence cannot reflect the integration of numerous environmental factors and long-term sustainability of river ecosystems (Soininen & Könönen, 2004).

On the other hand, biological communities of rivers reflect the overall ecological integrity by unifying various stressors, thus, providing a broad measure of their synergistic impacts. They integrate and reflect the effects of chemical and physical disturbances that occur over extended periods of time. These communities provide a holistic and an integrated measure of the health of the river (Chutter, 1998).

Biological monitoring, inclusive of multimetric approaches, acknowledges the turbulent and dynamic nature of rivers and offers one of the strongest available tools for diagnosing, minimizing, and preventing river degradation. The broad perspective offered by biological evaluations stands a better chance than narrow chemical criteria or conventional measures applied for assessment and sustaining of riverine ecosystems. In view of these facts, diatoms, benthic macro invertebrate, and macrophytes are extensively being used in rivers for bio assessment purposes all over the world (Hughes *et al.,* 2012).

The existing river water quality management in India, which is primarily based on physico-chemical parameters, makes it difficult to assess the quality status in terms of health of a water body. As such, there is an urgent need of bio monitoring of Indian rivers to ensure the "wholesomeness" and "health" of water bodies and the protection of the aquatic biodiversity.

Recently, biological monitoring is being increasingly employed in evaluating the water quality status of Indian rivers and efforts are being made to develop bio monitoring tools. However, studies on phytobenthic communities of Indian rivers have rarely been investigated in terms of bio monitoring (Gopal & Zutshi, 1998).

Diatoms have long been used to assess ecological conditions and monitor environmental change in streams and rivers throughout the world.

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Indices have been developed to monitor eutrophication (Descy & Coste, 1990; Kelly & Whitton, 1995; Coring *et al*., 1999; Kelly *et al.*, 2001), organic pollution (Watanabe *et al.,* 1986 and Rott *et al.*, 2003) and human disturbance (Fore & Grafe, 2002), and are now widely applied during routine water quality surveys.

By contrast, despite the changing water quality of surface waters, there are comparatively few studies using diatoms as indicators of pollution in the agricultural and densely populated regions of the sub-tropics and tropics (Juttner *et al.*, 2003). The Indian scenario of river water quality assessment is almost devoid of the studies on the utility of one of the most robust bio monitors, the diatoms.

Rationale for Using Diatoms: The Robust Indicators of Riverine Ecosystems

The diatoms (Bacillariophyceae) comprise a ubiquitous, highly successful and distinctive group of unicellular algae, with the most obvious distinguishing characteristic, the possession of siliceous cell walls (frustules).

As autotrophs, diatoms contribute significantly to the productivity of such ecosystems, frequently forming the base of aquatic food chains (Cox, 1996). They form the bulk of the periphytic communities in most of the rivers (Ponader & Charles, 2003) and have served as the most valuable indicator for the ecological assessment of rivers.

Several diatom taxa have been recognized as robust pollution indicators (Plate 1).

Numerous reasons, as to why diatoms are used as tools of bio monitoring, have been listed by Round (1991) and by De la Rey *et al.*, (2004). These include:

- Diatoms are non motile, ubiquitous, highly successful periphytic unicellular algae of aquatic ecosystems which form the base of riverine food chains.
- They have one of the shortest generation times of all biological indicators (~2 weeks). They reproduce and respond rapidly to environmental change and provide early indications of both pollution impacts and habitat restoration.
- They collectively show a broad range of tolerance along a gradient of aquatic productivity, with individual species having specific water chemistry requirements.
- Diatoms communities in rivers and streams respond directly and sensitively to many physical, chemical, and biological changes in river and stream ecosystems, such as temperature (Squires *et al.*, 1979; Descy & Mouvet, 1984), organic pollution (Watanabe *et al.*, 1986 and Rott *et al.*, 2003) and herbivory (Steinman *et al.*, 1987; McCormick & Stevenson, 1989) and hence serve as robust ecological indicators.
- They are highly sensitive to change in nutrient concentrations, supply rates and silica/phosphate ratios (Pan *et al.,* 1996; Kelly, 1998; Potapova & Charles, 2007). Each taxon has a specific optimum and tolerance for nutrients such as phosphate and nitrogen, which is quantifiable. Diatom indices have delivered the best results for the estimation of eutrophication in rivers (Hering *et al.*, 2006).
- Diatom assemblages are typically species-rich – augmenting the information gained from a diversity of ecological tolerances and providing more statistical power in inference models (John & Birks, 2010). The availability of interpretive software package such as OMNIDIA is of added advantage.
- Their ease of collection, preparation for observation, and storage (small sample volumes, no desiccation risk) for reference purposes also augments their use as bio indicators.
- Diatom frustules have a lasting permanence in sediments, such that sediment cores provide details of changes in the quality of the overlying water for as far back as one is able to search. This attribute alone has significant and far-reaching relevance for the determination of reference conditions, not only climatic but also the condition of the system prior to the intrusion of anthropogenic activities (Palaeoecological Reconstruction).
- The taxonomy of diatoms is comprehensively documented along with the tried and tested ecologically available associative information.

The European Water Framework Directive 2000/60/EC (European Parliament 2000) advocates the use of different organism groups such as benthic diatoms, macrophytes, invertebrates and fish to be used either singly or together in assessing the ecological integrity of stream ecosystems.

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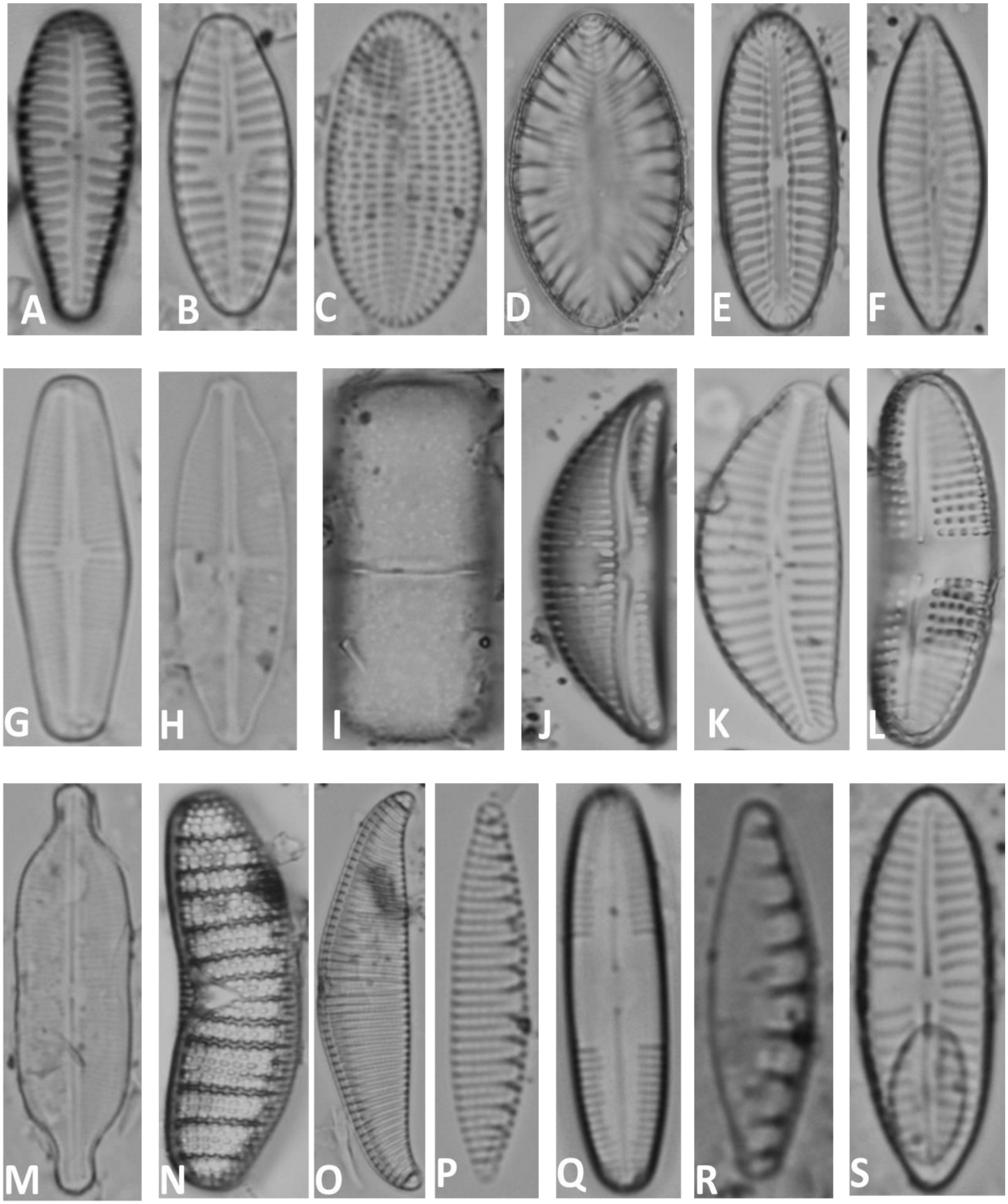

Plate 1: Some of the Indicator diatom genera
A. *Gomphonema* **B.** *Planothidium* **C.** *Cocconeis* **D.** *Surirella* **E.** *Diploneis* **F.** *Navicula*
G. *Achnanthidium* **H.** *Craticula* **I.** *Melosira* **J.** *Amphora* **K.** *Cymbella* **L.** *Achnanthes*
M. *Neidium* **N.***Epithemia* **O.** *Rhopalodia* **P.***Nitzschia* **Q.***Pinnularia* **R.***Denticula* **S.***Cymboplura*

In an extensive study of European streams, Hering *et al.*, (2006) compared these river bio indicators viz. diatoms, macrophytes, macro invertebrates and fish and showed that all four bio indicators were correlated to eutrophication, but the best results were obtained by use of diatoms. Macrophytes, invertebrate assemblages and fish may better reflect the impact of changes in the physical habitat in addition to certain chemical changes while the ecological status may better be defined by the diatoms (Hering *et al.*, 2006).

Diatoms occur in relatively diverse assemblages, and most species, especially the common ones, are relatively easily distinguished when compared to the assemblages of other algae and invertebrates. These can readily distinguished to species and subspecies levels based on their unique morphological features, whereas many other algal classes have more than one stages in a life cycle and some of these stages are either highly variable ontogenically (e.g. blue-green algae), cannot be distinguished without special reproductive structures (e.g. Zygnematales), or cannot be distinguished without culturing them (many unicellular green algae). As compared to fish and macro invertebrates, diatoms have shorter generation time. They reproduce and respond rapidly to environmental changes, thereby providing early warning indicators of both pollution increase and habitat restoration success (Stevenson *et al.*, 2010). Indices based on diatom composition give more accurate and valid predictions than benthic macro invertebrates, as they react directly to pollutants (Carlisle *et al.,* 2008). Even, the combined costs of sampling and sample assay are relatively low when compared to other organisms. Further, the samples can be easily archived for long periods of time for future analysis and long-term records. It is of additional advantage that the taxonomy of diatoms is generally well-documented (Krammer & Lange-Bertalot, 1986-91) where species identifications are largely based on frustule morphology.

Review of Literature

Assessments of environmental conditions in rivers using diatoms have a long history which can be traced back to the work of Kolkwitz & Marsson (1908). Autecological indices were developed to infer levels of pollution based on the species composition of assemblages and the ecological preferences and tolerances of taxa (e.g. Butcher, 1947; Fjerdingstad, 1950; Zelinka & Marvan, 1961; Lowe 1974; Lange-Bertalot, 1979) whereas Patrick's early monitoring studies (Patrick, 1949; Patrick *et al.,* 1954; Patrick & Strawbridge, 1963) relied primarily on diatom diversity as a general indicator of river health. These studies demonstrated the potential and robustness of diatoms that could enable their use to monitor river quality. After these first approaches, benthic diatoms in rivers became an obligatory bio indicator for use in several European and American countries in the late 90s. Investigation of benthic diatoms for the bio assessment of water quality was made mandatory by the Water Framework Directives (WFD) and European Parliament 2000 directive, 2000/60/EC.

Many diatom indices were developed around the world in the last decade of twentieth century (Figure 1), which were based on multiple taxa (genus or species). They are determined either in terms of presence/absence of key indicator species (eg. Palmers index) or are based on the weighted average equation of Zelinka & Marvan (1961). These included the development of trophic diatom index (TDI; Kelly & Whitton, 1995) in Great Britain, the generic diatom index (GDI; Rumeau & Coste, 1988), the specific pollution-sensitivity index (SPI; Cemagref, 1982) and the biological diatom index (BDI; Lenoir & Coste, 1996; Prygiel, 2002) in France, the eutrophication pollution diatom index (EPI-D; Dell'Uomo, 1996) in Italy, the Rott saprobic index (Rott *et al.*, 1997) and the Rott trophic index (Rott *et al.*, 1998) in Austria, the Schiefele & Kohmann trophic index (Schiefele & Kohmann, 1993) in Germany, and the CEE (Descy & Coste, 1991) in France and Belgium. The diatom assemblage index of organic pollution (DAIPo) was developed in Japan (Watanabe *et al.*, 1986) and the saprobic index (Pantle & Buck, 1955) in the USA. Further, the design and application of software programs such as OMNIDIA (Le Cointe *et al.*, 1993) for the calculation of diatom indices greatly enhanced the use of diatom-based assessment methods throughout the world. About 17 different diatom indices can be calculated with the help of this software (Table 1).

These diatom indices were later tested in neighbouring regions or countries by Goma *et al.*, (2004, 2005) in Catalonian Mediterranean rivers, Blanco *et al.*, (2008) in Spain, in Poland (Szczepocka & Szulc, 2009), Ziller & Montesanto (2004) in Greece, Torrisi & Dell Uomo (2006) in Italian rivers, Koster & Hubenener (2001) in German rivers, Kelly *et al.*, (2009) and Fawzi *et al.*, (2002) in Moroccan rivers.

Several studies report the use of diatom indices in regions with very different climates from the area they were created such as in East Africa (Bellinger *et al.*, 2006), in Malaysia (Maznah & Mansor, 2002), in Australia (Newall & Walsh, 2005), in the Himalayas of Nepal and India (Juttner *et al.*, 2003), in Iran (Atazadeh *et al.*, 2007), in South Africa (Walsh & Wepener, 2009), in Turkey (Gurbuz & Kivrak, 2002; Kalyoncu *et al.*, 2009a, b), in Vietnam (Duong *et al.*, 2006, 2007). Dela-Cruz *et al.*, (2006) tested the suitability of ecological tolerances/preferences of diatoms (Lange-Bertalot, 1979) defined in the northern hemisphere in Australian rivers. In all cases, even if these diatom indices and diatom tolerances were developed and defined in very different regions (e.g. Europe, USA, Japan) from those where they were tested, pollution assessment results were good and demonstrated the robustness of diatom bio monitoring (Rimet *et al.*, 2012). However, there are comparatively fewer studies using diatoms as indicators of pollution in the agricultural and densely populated regions of the sub-tropics and tropics such as the Indian Sub Continent (Juttner *et al.*, 2003).

Some authors developed their own diatom index for their specific studies when the existing diatom indices did not meet their requirements. Many new diatom indices were developed and tested such as an Australian diatom index (Chessman *et al.*, 2007), Quebec diatom index (Lavoie *et al.*, 2009), Biological water quality index in South America (Lobo *et al.*, 2004a, b), DI-CH in Switzerland (Hurlimann & Niederhauser, 2002), Generic diatom index in Taiwan (Wu & Kow, 2002), and a multimetric index in China (Tang *et al.*, 2006). In accordance with the WFD, Tison *et al.*, (2008) developed an index of ecological distance based on different pollution-sensitivity values of species between reference conditions and the polluted site.

In the present situation, diatom-based indices have gained considerable popularity throughout the world as a tool to provide an integrated reflection of water quality, and in support of management decisions for rivers and streams, particularly in the last two decades (Resende *et al.*, 2010 & Rimet, 2012)

Table 1: List of Some Popular Diatom Indices

S.No.	Abbreviation	Description
1.	SLA	Sladecek Index (Sladecek, 1986)
2.	DES	Descy Index (Descy, 1979)
3.	LandM	Leclercq & Maquet's Index (Leclercq & Maquet, 1987)
4.	SHE	Schiefele Idex (Steinberg & Schiefele, 1988)
5.	WAT	Watanabe Index or WAT Diatom Community Index (Watanabe *et al.*, 1986)
6.	TDI	Trophic Diatom Index (Kelly & Whitton, 1995)
7.	%PT	% Pollution Tolerant Taxa (Kelly & Whitton, 1995)
8.	IDG	Generic Diatom Index (Rumeau & Coste 1988, Coste & Ayphassorho 1991)
9.	CEE (CEC)	Commission for Economical Community Index (Descy & Coste,1991)
10.	IPS (PSI)	Specific Pollution Sensitivity Metric (Cemagreph, 1982)
11.	IBD	Biological Diatom Index (Lenoir & Coste, 1996)
12.	IDAP	Indice Diatomique Artois Picardie (Prygiel *et al.*, 1996)
13.	EPI-D	Eutrophication an Pollution Index (Dell'Uomo, 1996)
14.	DI-CH	Indice DI-CH (Hurrlimann & Neiderhauser, 2002)
15.	IDP	Pampean Diatom Index (Gómez & Licursi, 2001)
16.	LOBO	Biological Water Quality Index BWQI (*Lobo et al.*, 2004a)
17.	SID	Saprobic Index Diatom (Rott *et al.*, 1997)
18.	TID	Trophic Index Diatom (Rott *et al.*, 1999)

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TDI: Trophic Diatom Index
SPI: Specific Pollution Index
QDI: Quebec Diatom Index
PDI: Pampean Diatom Index
MI: Multimetric Index
DIAPo: Diatom Assemblage Index of Organic Pollution
GDI: Generic Diatom Index
BDI: Biological Diatom Index
CDI: Canadian Diatom Index
RTI: Rott Trophic Index
EPI-D: Eutrophication Pollution Diatom Index
RDI: River Diatom Index

Fig1.Application of diatom indices for ecological assessment of rivers around the world

National Scenario

Acknowledging the constraints of conventional analytical methods, biological monitoring is being increasingly employed in evaluating the water quality status of rivers and lakes in India and efforts are being made to develop bio monitoring tools (Gopal & Zutshi, 1998). Phytoplankton, nematodes (Tahseen *et al.,* 2007, 2011), zooplankton particularly rotifers and benthic macro invertebrates (Gopal & Zutshi, 1998; Jindal & Sharma, 2011) are being examined for their bio monitoring potential.

The CPCB has carried out a three year pilot study on the river Yamuna under the Indo-Dutch collaborative project and developed an integrated method for evaluation of water quality assessment combining the chemical and biological parameters (de Kruiijf *et al.,* 1992; Trivedi *et al.,* 1993; de Zwart & Trivedi, 1995). CPCB has also attempted bio mapping technique for certain rivers in India (CPCB 1999, 2005; Semwal & Akolkar, 2011) for classification and zoning of rivers in the form of a colour map which indicates various grades of water quality according to its level of ecological degradation in terms of clean, slight pollution, moderate pollution and severe pollution. Benthic macro-invertebrates were used as bio monitors in these projects.

Phytoplankton ecology and the use of algae as indicator of water pollution of different water bodies in India have been given frequent attention (Hosmani & Bharati, 1980; Gunale & Balakrishnan, 1981; Trivedy, 1986; Sudhaker *et al.,* 1994; Dwivedi & Pandey, 2002; Srivastava & Khare, 2009). Periphytic algae of river Ganga has been studied by Khare & Srivastava (2009) and Srivastava (2010). However, studies on bio monitoring of lotic water bodies by periphytic diatoms are scarce (Juttner *et al.,* 2003). Although the taxonomy of diatom flora has been well documented (Sarod & Kamat, 1984; Desikachary, 1989; Prasad & Mishra, 1992; Gandhi, 1957-1998; Nautiyal & Nautiyal, 1999; Nautiyal *et al.*, 2004 and Nautiyal & Verma, 2009; Karthick & Kociolek, 2011, 2012; Karthick *et al.*, 2015), studies of the ecology and application of diatom assemblages in assessment of water quality have been dismally neglected in the past. However, our knowledge of diatom indicators in the Indian rivers is just beginning to grow, through the investigations initiated by Nautiyal *et al.*, (1996 a-c), Badoni *et al.*, (1997) in the rivers (Alaknanda and Ganga) of Garhwal region in Uttarakhand, and Ormerod *et al.*, (1994), Rothfritz *et al.*, (1997), Johnson *et al.*, (1998), Jüttner & Cox (2001) in Nepal and Kumaun regions. This is so because there have been no investigations on the diatom flora in the Indian subcontinent on the scales of Europe, USA or Japan. Nautiyal & Verma (2009), Verma & Nautiyal (2012), Nautiyal *et al.*, (2013), and Verma (2015) have demonstrated high abundance of diatoms in the mountain rivers and streams in Himalaya and Central highlands implying their importance as primary producers in the stream and river ecosystems of this region.

Apart from the application of U.K. Trophic Diatom index to detect eutrophication in the streams of Kathmandu Valley and Middle Hills of India (Juttner *et al.*, 2003) and ecological studies of stream diatom communities in rivers of Central Western Ghats (Karthick, 2010), a comprehensive diatom index has neither been applied to nor developed for lotic water bodies in India. However, diatom indices have been extensively used for monitoring the wetlands of south India (Ramchandra & Solanki, 2007).

The diatoms are being used as indicator organisms in freshwater research and monitoring programmes such as "The Great Lakes Environmental Indicators project" and "Use of benthic diatoms for bio monitoring rivers in Europe" (Ector *et al.*, 2004). Investigation of benthic diatoms for the assessment of water quality was made mandatory by the Water Framework Directives (WFD) and European Parliament 2000 directive, 2000/60/EC and diatom indices are being used to monitor eutrophication, organic pollution and human disturbance leading to the formulation of national policies and regulatory frameworks for surface waters throughout the world. In spite of these facts, these robust bio monitors have rarely been used for bio assessment of the important rivers of Northern and Central India. Thus, information on their taxonomy, ecology and other aspects of biology will help in the management of the stream and river ecosystems.

CONCLUSION

Riverine ecosystems across the world are suffering the deleterious effects of anthropogenic activities, and the threats to the ecosystem health of river are likely to be amplified by the growing global climate change. There are urgent demands for holistic evaluation and restoration of these ecosystems. As such, bio monitoring techniques have become indispensible for the synergistic and integrated reflection of water quality assessment. Amongst various bio monitors recognized, the diatoms have served as one of the most robust and valuable indicators for the ecological assessment of rivers throughout the world particularly in Europe, North America, Australia, New Zealand and Japan, as is evident from the rich literature available. They have long been used to assess ecological conditions and monitor environmental health in streams and rivers and their role as a diagnostic tool can no longer be overlooked. As such, the Water Framework Directive and European Union (2000) have recommended the use of diatoms for the assessment of lotic water bodies. Diatom indices have been formulated and applied for different eco-regions round the globe.

So far as India is concerned, most of the research work available with reference to diatoms is taxonomical and our ecological knowledge about these benthic indicators has just begun. Efforts are being made to bridge this gap. Unfortunately, eco-assessment with diatom based indices is evidently lacking in the Indian scenario.

Diatom indices are mainly used to detect the trophic and saprobic status of river or stream and also help to know the causes of stress and possible abatement, mitigation and control measures. The practice of having a comprehensive data base on the state of aquatic ecosystem is limited and as such no comprehensive diatom index exists for the Indian scenario. As indices developed in other ecoregions should be tested before being applied in a basin that was never previously studied, major future efforts

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should be made in the direction of the development of a suitable diatom index(s) which would be specific to the ecoregion.

Thus, robust biological indicators, such as the diatoms, that can be indicative of specific water quality variables and state the actual "health" and ecological status of river ecosystems of India is the need of the hour. The diatom indices data of Indian rivers will help to classify its stress, and shall be useful for deciding their best possible use. There is definite potential for the use of numerical diatom indices as indicators of general water quality and the usefulness of these indices should be verified by further studies that cover a broader geographical area and a broader range of variables. The interpretation in terms of impact severity would immensely help to establish priorities for pollution control efforts in our country.

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