RELEVANCE OF ALGAE AS BIOLOGICAL INDICATORS OF POLLUTION MANAGEMENT STUDIES

ABSTRACT

Algae are multicellular or unicellular organisms that photosynthesize but lack the typical features such as leaves, roots, flowers and stems evident in higher vascular plants. They constitute the grasses of the waters. Algae differ in colour and class and occur in all water bodies including lotic and lentic fresh, brackish or salt. An attempt has been made here to establish the fact that as primary producers in aquatic systems, they can be utilised as bio-indicators to ascertain and qualify the outcome of pollutants and assess the degree of contamination in the ecosystem with the ultimate objective of ensuring that local resources used in the water sector applying biodiversity friendly management measures within their day-to-day practices. Among the benefits of utilising algae as bioindicators are short life cycles and rapid reproduction, direct influences by physical and chemical environmental factors, a cost effective monitoring tool, and ease of sampling, less labour and less impact on other organisms. Besides, their role in removing different pollutants including heavy metals and other toxic substances from aquatic environments qualify them as candidates for bionindicators.

Keywords: Algae, biomonitors, aquatic ecosystems, sustainable development

Introduction

Biomonitors are communities of organisms whose reactions are observed characteristically to assess a situation, giving clues for the state of the entire ecosystem (Gerhart, 1995). Bioindicators are measured components or metrics of the biota that are used to provide long term biologically significant information about the ecosystem status or trends. They are different from the responses of human impact from natural variability when supported by predictive modelling and sound ecological theory.

Types of biomonitors

Based on the purpose of bioindication, three known forms of bioindicators exist:

1. Compliance indicators
2. Diagnostic indicators
3. Early warning indicators

While compliance indicators are measured at the population, community or ecosystem level and emphasis is focused on issues as the sustainability of the population or community as a whole, as in fish population, diagnostic and early warning indicators are measured on the individual or suborganismal level with emphasis on early warning indicators focussing on rapid and sensitive responses to environmental changes.

Based on their applications, three forms of bioindicators are evident

1. Environmental indicator – species or group of species responding predictably to environmental disturbance or change as in bioassay organisms
2. Ecological indicators – Species identified to be sensitive to pollution, habitat disintegration or other stress and
3. Biodiversity indicator – Species richness of an indicator toxin is used as indicator for species richness of a community

Bioindicators can also be grouped based on the type of the organisms used. On this basis, bioindicators are classified as:

1. Animal indicators – zooplankton, protozoa, crustaceans, amphipod and copopods, insects, biovalves, mollusks, gastropods, fish, amphibians
2. Plant indicators – algae, macrophytes and
3. Microbial indicator – algae, fungi, bacteria and other microbial life form.

Major features of bioindicator organisms include

1. Sensitive to change
2. Easily measure and informative
3. Consistence
4. Better than or complementary to other potential indicators
5. Ecologically understood/friendliness
6. Colourful, large, charismatic or unusual
7. Biologically sustainable
8. Ability to change physiologically, chemically or behaviourally
9. Used in water quality assessments
10. Bioindicators reveal the occurrence of a pollutant
11. Used to assess the condition of an ecosystem
12. Some algae show clear preference for particular lake conditions hence can be utilised as potential bioindicators

Usefulness of biomonitoring

1. Where the indicated environmental factor cannot be measured
2. Where the specified factor is difficult to measure e.g. pesticides and their deposits or complex lethal effluents covering many interacting chemicals and
3. Where the ecological feature is easy to measure but hard to deduce e.g. whether the observed changes have environmental impact.

Algae as biomonitors

Algae comprises of all holophytic organisms as well as their abundant colourless derivations that fail to attain the point of differentiation physiognomies of archegoniate plants (Hill *et al.*, 2000). They are a collection of relatively simple organisms that are photosynthetic, non vascular plants containing chlorophyll and possessing simple reproductive structures (Bhatnager and Bhardwarji, 2013). Algae are also viewed as a very large group of non-flowering plants containing chlorophyll but lacking true stems, roots, leaves and vascular tissues. Algae can be found in aquatic ecosystems such as ocean, rivers, seas, ponds, lakes and streams (Hazzeman, 2008; Bhatnager and Bhardwaji, 2013). Algae may be multicellular or unicellular. Some examples of algae used in biomonitoring include diatoms such as *Fragillaria spp*, Spirogyra spp, *Peridinum spp* and *Nodularia spp.* (Favero and Frigo, 2002).

The aquatic algae as the significant basic producers in inland and marine water perform a vital role to the entire ecosystem. The algae directly reflect quality in most water bodies (Zhou *et al.*, 2008). Exposure of algae to pollutants of varying types and gravity can directly cause the disorder of regular metabolism and biological activities including photosynthetic production and usage, reduction of cytochromas, cellular mutation, putrescence and other cell aberrations including death. Besides as primary producers there could be bioaccumulation which may result in health risks or hazards (He and Chen, 2014).

Algal groups possess many features as biomonitors of spatial and temporal environmental changes (Omar, 2010). Algae parameter especially functional and structural varieties as including short life cycles and rapid reproduction, ease of sampling and cost effectiveness requiring few persons for assessment and their user impact on other organisms.

Other factors include:

1. Algae wide temporal and spatial distribution (Mahadev and Hosamani, 2005).
2. Species availability
3. Response to environmental variations due to pollution
4. Occurrence in large quantities
5. Ease of detection and sampling
6. The occurrence of certain algae are well associated with some specific type of pollution particularly to organic pollution
7. Algae have been found to be important indicators of water quality and several lakes are classified based on their prevalent phytoplankton group (Tapia, 2008).
8. They have also been utilised in gas and oil exploration sites
9. Wide geographical distribution (Jafari *et al.*, 2006).
10. Ease of culturing in the laboratory
11. They are relatively in expensive and create minimal impact on resident biota (Wunsarn *et al.*, 2002).
12. Standard methods exist in their evaluation of efficient and non-taxonomic structural features (Zhou *et al*., 2008).
13. Biological communities integrate the outcome of different stressors thus provide a braod measure of their impact (Raut *et al.*, 2010).

14. Communities of algae integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions (Vashishtal *et al.,* 2008).
15. Routine observation of biological communities can be quite inexpensive, especially when compared to the cost of evaluating toxic pollutants, either chemically or with toxicity tests (Priyadarshani *et al.,* 2011).
16. The condition of biological communities is of direct importance to the public as a measure of a pollution free environment (Olawton and Cooke, 1994).
17. Could also be a useful phytoremediation technology to restore water quality due to high bioaccumulation abilities (Zhou *et al*., 2008).

Algae species used in pollution biomonitoring include the diatoms, chlorophytes, cyanophytes, periphyton and dinoflagellates. Table 1 shows the algae and the industrial wastes they are indicating. The pollution index of algae genera at different stations of Negapur and Chandapur dams using Palmer's pollution index is presented in Tables 2 and 3. The mean algal attributes and associated indicators commonly used in monitoring programme is shown in Table 4.

Table 1: Algae indicating different industrial wastes

Industrial waste	**Indicating algae**
Distillery waste	*Chalamydobotrys sp., Chloroachis gracillima (Chlorophyceae)*
Oil water	*Amphora avails (Bacillariophyceae), Trachelomonas sp. (Euglenophyceae)*
Hydrogen suphide wastes	*Cymbella Ventricosa, Navicula minima (Bacillariophyyceae)*
Iron wastes	*Chlorophyceae, Surirella linearis (Bacillariophyceae)*
Chromium wastes	*Tetraspora sp (Chlorophyceae), Navicula atomus (Bacillariophyceae)*
Salt brine	*Scenedesmus byugatus (Chlorophyceae), Diatom elongatum (Bacellariophyceae)*
Copper waste	*Symploca erecta (Cynoohyceae), Asterionella Formosa (Bacellariophyceae)*
Phenoloic waste	*Fragilaria virescens, Pinnularia borealis (Bacillariophyceae)*

Source: Raut *et al.* (2010)

Table 2: Pollution index of algal genera at different stations of Negapur and Chandapur dams

S/N	Group/genera	Palmers Pollution Index					
		NG 1	NG 2	NG 3	CH 1	CH 2	CH 3
Chlorophyceae							
	Scendesmus	4	2	5	6	-	2
	Chlorella	3	2	4	3	3	2
	Spirogyra	3	2	2	2	2	2
	Pediatrum	3	2	2	3	2	2
	Ulothrix	2	1	-	2	-	-
	Clostarium	1	1	1	1	-	1
	Cosmarium	1	1	1	1	-	-
Cynaophyceae							
	Oscillotoria	4	4	-	5	3	4
	Phromodium	2	2	2	2	1	2
	Microcystis	1	-	-	1	-	-
	Anabaena	1	-	-	1	1	1
	Spirulina	1	1	-	1	1	1
Diatoms							
	Nitzschia	3	1	2	3	3	3
	Navicula	1	1	1	1	1	-
	Gamphonema	1	1	-	-	1	-
	Surirella	1	1	1	-	1	-
	Cymbella	2	-	2	2	-	2
	Achinathes	1	1	2	1	1	1
Euglenophyceae							
	Euglena	1	1	-	1	2	1
	Pachus	-	-	-	2	2	2
	Trachelomenas				1	1	1
	Total score	**36**	**24**	**25**	**39**	**25**	**27**

Source Raut *et al*. (2010)

Key:

NG= Negapur

CH = Chandapur

Table 3: Pollution indicator genera/tolerant genera from three stations of Negapur dam and Chandapur dam near Parli in order of decreasing emphasis

Genus	Group	Total Conc.	NG 1	NG2	NG3	CH1	CH2	CH3
Euglena	E	120	+	-	-	+	+	-
Oscillatoria	B	150	+	+	-	+	+	-
Scenedesmus	G	112	+	+	+	+	-	+
Chlorella	G	109	+	+	+	+	+	+
Nitzsechia	D	104	+	-	+	+	-	-
Navicula	D	95	-	-	+	+	-	+
Stigeclonium	G	-	-	-	-	-	-	-
Synedra	D	80	+	+	+	+	+	+
Phacus	E	-	-	-	-	+	+	+
Phormodium	B	75	-	-	+	+	-	+
Melosira	D	-	-	-	-	-	-	-
Gomphonema	D	62	+	-	+	-	-	-
Cyclotella	D	-	-	-	-	-	-	-
Microcystis	B	50	-	-	+	+	-	-
Spirogyra	G	42		+	+	+	+	-
Anabaena	A	40	+	+	+	+	+	+
Pediastrum	G	35	+	+	+	+	+	+
Trachelomonas	E	-	-	-	-	+	-	-
Fragilaria	D	-	-	-	-	-	-	-
Ulothorix	G	-	-	-	+	-	+	-
Surirella	D	30	+	-	-	+	-	-
Lyngbya	B	-	-	-	-	-	-	-
Spirulina	B	29	+	+	+	+	+	+
Cymbella	D	25	+	-	+	+	-	-
Coelastrum	G	24	+	+	+	+	+	+
Cladophora	G	-	-	-	-	-	-	-
Hantzschia	D	-	-	-	-	-	-	-

Achinathes	D	22	-	+	+	+	-	-
Pinnularia	D	-	-	-	-	-	-	-
Cocconeis	D	-	-	-	-	-	-	-
Cosmarium	G	18	+	+	+	+	+	+
Gonium	G	-	-	-	-	-	-	-
Stauroneis	D	-	-	-	-	-	-	-
Crucigenia	B	-	-	-	-	-	-	-

Source Raut *et al.* (2010)

Key:

NG = Negapur

CH = Chandapur

+ = Increase in organic pollution

- = Decrease inorganic pollution

Table 4: Mean algal attributes and associated indicators commonly used in monitoring programs

Attribute	Indicator
Community structure	
Biomass	Ash-free-dry-weight (AFDW)
	Chlorophyll a
	Autotrophic index (AFDW: Chlorophyll a)
	Cell biovolume
Diversity	Species diversity (diatom)
	Species richness
Composition	Multivariate analysis (diatom)
	Similarity indices (diatom)
Community metabolism	
Net production	Change in biomass
	Relative specific growth rate
Productivity	Oxygen evolution
	Radioisotopic tracer (^{14}C)
	Photosynthetic capacity
Bioaccumulation	Nutrients
	Metals
Metabolic state	Adenylate energy charge
Biomoelcules	Ribonucleic acid
Enzyme activity	Alkaline phosphatase activity
Population analyses	
Indicator species	pH index
	Pollution tolerance index
	Saprobien index
	Diatom index
	Microalgal spectral analysis

	Trophic index
Growth	Algal growth potential

Source: Omar (2010).

Significance of algae in aquatic ecosystems

1. Diatoms are ubiquitoes in both lakes and rivers as well as in other moist conditions. There is sufficient light for photosynthesis even moist soils. Diatoms therefore, can provide bioindication of water conditions (He and Chen, 2014) which are beyond the tolerance of many other biota used for monitoring. Diatoms are also cosmopolitan in distribution. Many diatom taxa have been identified throughout the world (Jafari and Quanale, 2006; Tapia, 2008). Similarly, diatoms are sensitive to and appear to have a consistent tolerance of a wide range of environmental parameters such as light, moisture, current velocity, pH, salinity, oxygen and inorganic and organic nutrients (Belore *et al*., 2002). Diatoms also appear in large numbers and often show considerable species richness. These characteristic features make them to stand out as active bioindicators of aquatic ecosystems (Almeida, 2001).
2. The green algae which are the chlorophytes are responsible for most of the primary productivity of near shore ecosystems (Kumar *et al*., 2008). The polysaccharides of cell wall of this group of algae provide amino, carboxyl, phosphate and sulphate groups for metal binding and in addition. They all have ion exchange properties. Their usage in biomonitoring is centred on the fact that they most green algae have the capacity to reflect the concentrations of metal in the ambient seawater.
3. Some particular species of the cyanophyta have been involved in biomonitoring studies (Olawton and Cooke, 1994). It is opined that their ability to store toxins make them significant agent in remediation studies.
4. Periphyton are one of the most essential algae connected with substrates in aquatic ecosystems (Hill *et al.*, 2000). Their use as biological monitoring tool has also been reported by Omar (2010). Periphyton show high diversity and are key factor in nutrient cycling and energy flow in aquatic systems. They are sensitive to several environmental conditions which can be detected by changes in species composition, cell density, ash free, dry mass, chlorophyll and enzyme activity hence can be used as indicators of ecological systems

(Omar, 2010). Their advantages include fixed habitats hence cannot avoid pollution, ability to speedily recolonize habitats after disturbances in water. Additionally, the ease of sample, preparation for analysis for wide spread and common taxa make them to be effective and easy bioindicator agents.

5. Other algae employed for bioindication studies are the dinoflagellates. These algae have hair-like projection used for locomotion. They are the cause of the toxic red tides that are quite frequent along sections of the coast of North America (Chakraborty and Bhattacharya, 2014).

Approaches for biomonitoring of aquatic systems using algae

1. Species concept approach (Saproblem system – This approach is common in municipal and waste water monitoring and differentiates between clean streams and polluted waters. Here the periphytic algal species composition is calculated. Chemical stresses in aquatic ecosystems help to adjust the taxonomic composition of the algal population using a decrease of sensitive species and an upsurge in the number of tolerant species (Vashishta *et al*., 2008).
2. Hierarchical framework approach – This approach involves the growth of the periphyton indices of aquatic ecosystems. Here, the composite calculation of biotic integrity, ecological sustainability and tropic condition is done (Mahadev and Hassarnani, 2005).
3. Algae indices of community structure. This refers to the algal community structure in terms of similarity, rickness, diversity or evenness. This approach stems from the general assumption that healthy environment is characterised by a greater diversity of organisms when compared with degraded environments. Opinion is however divided as to the exact relationship between diversity of organisms and the environmental quality as more other complexity may be involved than ever imagined. Omar (2010) stated that to accurately estimate the water quality using species diversity, it is necessary to precisely define the species that comprise the community and to have a thorough knowledge of their autecology (Priyadarshani *et al*., 2011).
4. Multivariate analysis- this approach is based on the correlation of organism assembled (especially diatoms) with environmental data. It is viewed that the methods which compare the distribution patterns of diatom communities in the rivers with physio-chemical

parameters allow for the analysis of the relationship between biota and abiotic variables (Olowton and Cook, 1994).

5. Non-taxonomic measure of algae- This approach notes that chlorophyll and other photosynthetic pigments and biochemical components such as ATP and DNA can be used to detect effects not implicated by taxonomic analysis for example, periphyton algae, fatty acid biomarkers showed differences in the taxonomic composition of periphtyon between reference and polluted sites. This approach views that chlorophyll as an essential part of ecological studies, both as a productivity indicator or index of the photosynthetic potential and as an indicator of nutrient stress or community conditions. Although these methods can be employed and detailed information on algae as bioindicators of water quality.

Disadvantages of algae as bioindicator organisms

1. They affect the taste and smell of water (Tapia, 2008).
2. They could block sunshine stemming from algal bloom
3. Reduction of water front properties
4. Could be influenced by other factors apart from stress
5. The functionality is habitat- dependent and scale dependent
6. Some algae can release some toxic substances. Algal bloom could constitute environmental hazards that impair water quality of water bodies. Care should however be taken on the choice of algae to be used as biomonitors (Hill *et al*., 2000).
7. Measurements obtained may not be generalizable owing to the perturbations in water bodies. Besides, no one group of organisms is always best suited for detecting and assessing the anthropogenic stress associated with man and his activities hence it is recommenced that indicators derived from several groups of organisms should be included in water quality monitoring programmes to provide a more comprehensive signal of an alterations in ecosystem.
8. Limited use of such species is expected in the actual investigators due to some of their biological features.
9. Their small size makes it difficult for isolation work

10. The complexity of phytoplankton communities makes the monitoring data serious for the actual evaluation.
11. Algae may be influenced by factors other than stress and disturbance

Conclusion

The study has established that algae can be used as biological indicators of pollution management studies. The groups of algae used include the diatoms, green algae, blue-green algae, peryphyton and the dinoflgellates. Among the advantages of using algae in biominitoring are short life cycles, rapid reproduction, ease of sampling, cost effectiveness, their wide distribution, occurrence in large numbers, ease of culturing in the laboratory and status of biological community. Their use as biomonitor should be employed with caution as they may be influenced by other factors other than stress and disturbance.

References

Almeida, S.F.P. (2001). Use of diatoms for freshwater qulity evaluation in Potugak. *Linnetical* 20(2):205-213.

Belore, M. Winter, J. and Duthie, H. (2002). Use of diatoms and macroinvertebrates as biomonitors of water quality in Southern Ontario Rivers. *Canadian Water Resources Journal* 27:457 -484.

Bhatnager, M. and Bhardwaji, N. (2013). Biodiversity of algal flora in River Chambal at Kotal, Rajasthan. *Nature and Environmental Pollution Technology* 12(3):547-549.

Chakraborty, S., Bhattacharya, T., Singh, G. and Maity, J.P. (2014). Benthic macroalgae as biological indicators of heavy metal pollution in the marine environments: a biomonitoring approach for pollution assessment. *Ecological and Environmetal Safety* **100**(1):61-68.

Favero, N. and Frigo, M. G. (2002). Biomonitoring of metal availability in the Southern basin of the lagoon of Venice (Italy) by means of macroalgae. *Water, Air and Soil Pollution* 140:231-246.

Gerhartt, A. (1995). Bioindicator species and their use in bioindicatoring. *Environmental Monitoring* 1:16-23

Hazzeman, H. (2008). Periphytic algae as bioindicator of river pollution in Sungai Patani, Kedah, M.Sc. Dissertation, University Sanins, Malaysia. 127p

He, J. and Cen, J.P. (2014). A comprehensive review on biosorption of heavy metals by algal bimass: materials, performances, chemistry and modeling simulation tools. *Bioresource Technology* **160**:67-68.

Hill, B.H. Herlihy, A.T., Kaufmann, P.R., Stevenson, R.J., McCarmick, F.H. and Johnson, C.B. (2000). Use of periphyton assemblage data in an index of biotic integrity. *Journal of North American Benthological Society 19*(1):50-57.

Jafari, N.G. and Gunale, Y.R. (2006). Hydrological study of algae of an urban freshwater river. *Journal of Applied Sciences and Environmental Management* 10(2):153-158.

Kumar, K., Dhadse, S., Chaudhari, P.R. and Wate, S.R. (2008). A biomonitoring of plankton to assess quality of water in lakes of Nagpur City. Sengupta, M. and Dalwani, R. (ed.). Proceedings of TAAI 2007: The 12th World Lake Conference. Pp160 – 164.

Mahadev, J. and Hosamani, S.P. (2005). Algae for biomonitoring of organic pollution in two lakes of Mysore City. *National Environmental Pollution Technology* 4:97-99.

Olawton, L.A.and Cooke, G.A. (1994). Cyarobacteria (Blue-green algae) toxis and their significance. *Journal of the World Aquaculture Society* 17(4):173-175.

Omar, W.M. (2010). Perspective on the use of algae as biological indication for monitoring and protecting aquatic environments, with special reference to Malaysian freshwater ecosystems. *Trop*ical *Life Science Research* 21(2):51-67.

Priyadarshani, I., Sahu, D. and Rath, B. (2011). Microalgal bioremediation: current practices and prospective. *Journal of Biochemical Technology 3(3)*:299-304.

Raut, K.S., Kachare, S.V., Pathan, T.S., Shinde, S.E., Dabhade, V.F. and Sonawane, D.L. (2010). Utilization of algae as biomonitors indicators of water quality of Negapur and Chandapur Dams new Parli V. Town district, Beed Mararashhtra, India. *International Journal of Current Science 4:*52-54.

Tapia, P.M. (2008). Diatoms as biomonitor of pollution in the mantaro river, Central Andes, Peru. *International Journal of Environment and Health* 2(1)82-91.

Vashishta, B.R., Singh, A.K. and Singh, V.P. (2008). Botany for degree students: algae S. Chand and Company Ltd., New Delhi, India.

Wunsam, S. Cattanee, A. and Bourassa, N. (2002). Comparing diatoms species, genera and size in biomonitoring: a case study from streams in the laurentians (Qu' ebec, Canada). *Freshwater Biology* 47:325-340

Zhou, Q., Zhang, I. F. J., Shi, j. and Jiang, G. (2008). Biomonitoring: an appealing tool for assessment of metal pollution in the aquatic ecosystem. *Analytical Chemistry ACTA* 606:135-150.