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Biological Assessment of Water Pollution Using Periphyton Productivity: A Review

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ABSTRACT

Periphyton is an entire community of organisms and its productivity is quite significant in relation to total primary production, which is often equal to or exceeding as biomass (ash free dry weight) in terms of phytopigment content (chlorophyll-*a*) to assess water pollution. Productivity is caused by increased nutrient enrichment due to sewage and agro-industries. Periphyton is useful as biological indicator of water pollution. Several biotic and abiotic environmental factors are affected due to periphyton growth. Its growth depends upon some factors such as temperature, light, pH, DO and nutrients (N and P). Productivity is often limited by nitrogen (N) and phosphorus (P) availability as periphyton use N compounds and phosphorus for their growth. Chlorophyll-*a* alone is an inadequate predictor of the relative contribution of different algal communities to the total primary production. Periphyton production is associated with various factors and can be evaluated by physico-chemical, chlorophyll and biomass estimation and causes several deleterious effects to water quality.

INTRODUCTION

Water is very important for the survival of all life forms and is necessary for every action of human beings (Dhar et al. 1986). Water pollution is foreword of chemical, physical and biological agents into water that degrades water quality and negatively affects the organisms. It is a significant problem in our country as approximately 70% of its surface water and an upward percentage of its groundwater reserves are unhygienic by biological, toxic, organic and inorganic pollutants (Murty & Kumar 2011). The effects of anthropogenic activities in the receiving systems can be assessed by measuring changes in population structural parameters with biodiversity indicators (diversity, species and taxonomic richness), biotic indices, community structure (multivariate methods) or changes in functional parameters such as energy allocated to development (Metcalfe & Smith 1996, Naylor et al. 1989). River pollution in India has currently reached a peak of disaster due to unexpected urbanization and fast growth of industrialization (Saksena et al. 2008). The water quality deterioration is mostly due to human actions such as release of industrial and sewage wastes and agricultural overflow which are the main reasons of ecological injure, which pose serious health hazards (Meitei et al. 2004).

BIOLOGICAL ASSESSMENT

Biological assessment is a method in which living organisms are used to determine the situation of the environment (Clements et al. 2000). Bioassessment can be made by benthic large scale spineless creatures, fish and periphyton; however benthic full scale spineless creatures are regularly the array of decision. They have a few attributes that make them especially helpful for bioassessment: (1) Benthic large scale spineless creatures unfold in a wide range of freshwater territory. (2) There are numerous classes of benthic large scale spineless creatures, and among these classes there is an extensive variety that affects the ability to contamination and natural anxiety. (3) They have generally stationary propensities so they are liable to be presented to contamination or ecological anxiety. (4) Their life cycles are adequately long and the group will not recuperate so rapidly that the effect will go undetected. (5) Sampling the benthic full scale invertebrate array is moderately basic and does not require confused gadgets or incredible exertion. (6) The taxonomic recognizable proof is quite often the simplest to the family level and generally moderately simple to the sort level (Voshell et al. 1997). Various hypothetical and useful considerations on the utilization of exact groups in biological assessment methods are obtainable as mentioned in Table 1.

Biotic indices and biotic scores are functional to assess the biological water quality of flowing water, and mainly belong to macroinvertebrate population. Biotic indices and scores can measure various types of environmental stress,

Table 1: Various groups used for biological assessment of water quality.

Group	References
Bacteria	De Zwart & Slooff (1983); Ross & Henebry (1989)
Algae	Tubbing et al. (1994); Steinberg & Schiefele (1988)
Macrophytes	Hellawell (1986); Rademakers & Wolfert (1994)
Macroinvertebrates	Hellawell (1986), Metcalfe (1989), De Pauw & Hawkes (1993)
Fish	Hellawell (1986)

Table 2: Main features of bioindicators in the assessment of environmental change (Adams 2005).

Major features	Bioindicator
Types of response	Individual community
Primary indicator	Effects
Sensitivity to stressors	Low
Relationship to cause	Low
Response variability	Low
Specificity to stressors	Low-moderate
Timescale of response	Long
Ecological relevance	High
Analysis requirement (fixed sample)	Any time after collection

organic pollution, acid water, etc. The biotic indices are based upon two principles: a) that macroinvertebrate groups Plecoptera (stoneflies), Ephemeroptera (mayflies), Trichoptera (caddisflies), Gammarus, Asellus, red Chironomids and Tubificidae disappear in the order mentioned, as pollution increases; b) the number of taxonomic groups is reduced as organic pollution increases (Knoben et al. 1995). Main features of bioindicators in the assessment of environmental change are given in Table 2. Biotic indices and biotic scores of periphyton and diatoms communities are depicted in Table 3.

PERIPHYTON

Periphyton comprises principally of connected green growth, yet can likewise incorporate rotifers, protozoa and microbes appended to seagoing substrates alongside free living microorganisms found among the joint structures. Periphyton contain a collection of creatures developing on free surfaces of any articles, for example, plants, old leaves, woods, stones, rocks and plastic sheets submerged in water (Rashid et al. 2013a), and it is an imperative part of numerous lotic frameworks, impacting supplement and carbon cycling, invertebrate piece and different parts of the framework and progress (Lock et al. 1984).

Biological indicator: The periphyton is valuable as natural pointer of contamination, as they are for the most part sessile and consequently cannot keep away from contact with the waste effluents (Rashid et al. 2013b). Natural groups are great markers of water quality (Whitton & Rott 1996, Hill et al. 2000). Diatoms, specifically are valuable natural markers since they are found in abundance in most lotic biological systems. Diatoms and numerous other green growths can be distinguished to species by experienced algologists. The immense quantities of the species give numerous pointers of ecological change and the particular states of the environment. Diatom species are differentially adjusted to an extensive variety of environmental conditions. Small period sign of coverage to ecological pressure, is usually expressed at suborganismal levels, including bimolecular, biochemical and physiological responses (Adams 2005).

Periphyton productivity: Periphyton assumes a noteworthy part in the working of the amphibian biological system, delivering huge standing yields and subsequently contributes much to the productivity of crisp water environments

Table 3: Biotic indices and biotic scores of periphyton and diatoms communities (References cited from De Pauw et al. 1992).

A = Periphyton, D = Diatoms

Biotic indices	Communities	References
Cemagref Diatom Index (IDC)	PAD	Cemagref (1984)
Diatom Index (IDD)	AD	Descy (1979)
Diatom Index (ILB)	AD	Lange-Bertelot (1979)
Diatom Index (IPS)	AD	Cemagref (1982-1984)
Diatom Index (IFL)	AD	Fabri & Leclerq (1984-1986)
Diatom Index (ILM)	AD	Leclerq & Maquet (1987)
Diatom Index (CEC)	AD	Descy & Coste (1991)
Generic Diatom Index (IDG)	AD	Rumeaux & Coste (1988)
Median Diatomic Index (MI)	AD	Bazerque et al. (1989)
Diatom Index(PI)	AD	Palmer (1969)
Diatom Index(GDI)	AD	Coste & Ayphassorho (1991)
Diatom Index(IADP)	AD	Prygiel et al. (1996)
Diatom Index(TDI)	AD	Kelly & Whitton (1995)

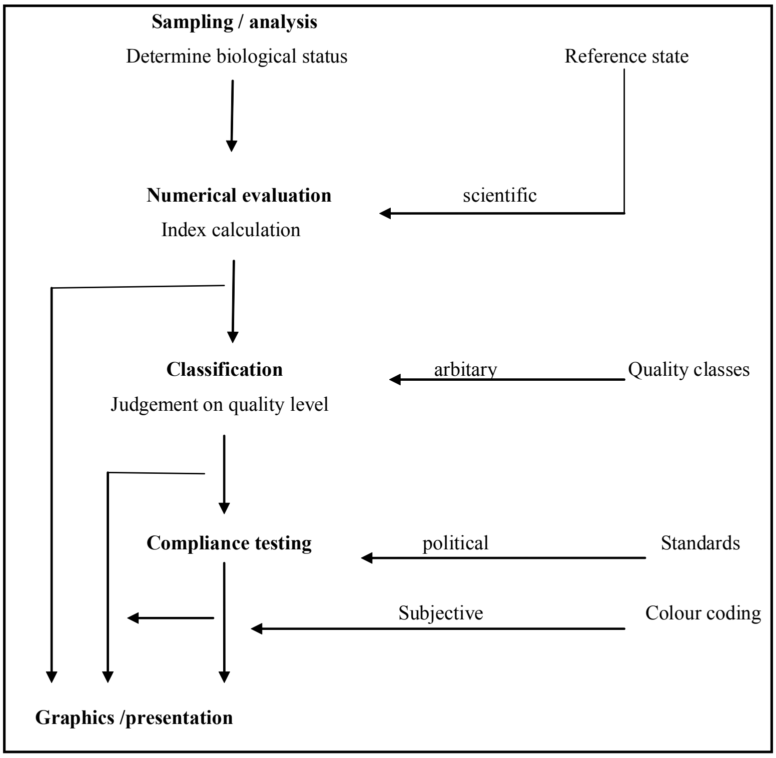

Fig. 1: Elements of biological assessment methods.

(Kaul et al. 1980, Pandit 1980, 1984, Pandit et al. 1985, Sarwar 1999). Investigations of essential productivity in oceanic frameworks frequently focus on phytoplankton groups and disregard conceivable commitments from periphyton (Catherine 2006). Periphyton productivity might be an imperative donor to altered carbon in the lake (Loeb et al. 1983, Hawes & Smith 1994, Vander Zanden & Vadeboncoeur 2002). The periphyton contributes generously to littoral zone efficiency and assumes a critical part in the littoral nourishment web (Takamura 1988). Occasional changes in periphyton productivity may impact the littoral sustenance web, generating a bigger scale regular example in this tropical framework. Furthermore, it is accounted for that the green growth has a part in deciding water contamination and cleaning wastewater (Colak & Kaya 1988). Subjective and quantitative determination of the algal flora are fundamental for deciding the amphibian efficiency as they are the boss wellspring of sustenance for seagoing creatures including fish. The algal flora is generally circulated and is a vital segment of different biological communities like marine, new water waterways, lakes and streams and so on. It is the fundamental sustenance for seagoing fauna and fish (Rashid et al. 2013). Light, temperature and supplement together characterize the potential for essential generation while water speed and touching impact the improvement of biomass (Kelly & Whitton 1995). Periphyton productivity can be assessed as biomass (dry and powder free dry weight), phyto-colour substance, determination of chosen components or component proportions, natural matter, and caloric substance, and so on. A few scientists evaluated periphyton biomass or productivity through infinitesimal numbering strategies (Brown 1976, Cattaeno & Kalf 1978).

Growth of periphyton: Effects of biologically treated bleached-kraft pulp mill effluent (BKME) on aquatic communities (periphyton, benthic invertebrates and fish) can be growth enhancing due to nutrient and organic enrichment or growth inhibiting due to chronic contaminant toxicity (McLeay & Associates Ltd. 1987, Wassenaar & Culp 1995). Typically, enrichment effects are evident at lower effluent concentrations (Bothwell & Stockner 1980, Hall et al. 1991) and contaminant effects are evident at higher concentrations (NCPIASI 1982, Lowell et al. 1995). In temperate regions, periphyton development on riverbed substrate is a typical issue that influences various waterway values, life supporting limit, contact diversion, aesthetics and trout fishery. Extreme crest periphyton biomass is reliant on times of steady or low stream, and on the nonappearance of shade from riparian vegetation and low turbidity. Once these conditions are met, the rate of advancement and top biomass is for the most part firmly controlled by the convergence of bioavailable N and P in water (Biggs 1996b). Entire mat supplement impediment comprises of two parts (Bothwell 1989): 1. Particular development rate constraint, 2. Mat development restriction.

BIOTIC AND ABIOTIC FACTORS

Ward & Stanford (1979) likewise recommended that water stream, temperature and substrates are the central point deciding the arrangement and plenitude of benthic spineless creatures. Parcel of work is done on lotic biological communities in India by a few specialists, for example, Krishnamoorthy & Sarkar (1979), Khan (1982), Shukla et al. (1989), Mitra & Nandi (1998), Sharma (1986), Sharma et al. (2004, 2008, 2009), Joshi et al. (2007), Sharma & Chowdhary (2011), Habib & Yosuf (2012), Mishra & Nautiyal (2012) and Palit et al. (2013).

Temperature: The periphyton indicates astounding spatial and worldly heterogeneity, with varieties in its structure, thickness, biomass and productivity (Stevenson 1997). An expansion in the temperature of freshwater frameworks may have outcomes concerning species assorted qualities (Rouse et al. 1997). Temperature sways compound and natural procedures through CO_2 for the most part affecting photosynthesis of the leaves in higher plants (Koch & Mooney 1996). Every kind of green growth has a particular ideal scope of temperature in which it develops. However, the ones that lean toward middle of the road temperature reach, are most essential to ponder in light and become plentiful in many spots (Hickman 1974). Because of their short life cycle and their capacity to react rapidly to changing natural components, diatoms are a decent decision in measuring reactions to an element of expanding temperature (Dixit et al. 1992). Temperature stimulates growth and metabolism of all marine biota, including phytoplankton at different rates (Brown et al. 2004).

Stream light: In periphyton, causes of light limitation include shading effects by riparian vegetation, competition for light with phytoplankton, light absorption by the water column, and self-shading effects within the periphyton mat itself (Hillebrand 2005). Depth-level fluctuations affect both, the magnitude of wave-induced shear stress and the amount of light available for photosynthesis, with important consequences on the structure and functions of periphytic communities (Stevenson & Stoermer 1981, Hoagland & Peterson 1990, Jonsson 1987). Because light fuels phototrophic organisms, its limitation is as important as that of nutrients for primary production with upwelling consequences for a variety of consumers (Hill 1996, Vadeboncoeur & Lodge 2000, Hillebrand 2005). Periphyton can restrict seagrass photosynthesis by reflecting and engrossing accessible light before it can achieve leaf surfaces (Bulthuis & Woelkerling 1983, Orth & Moore 1983, Neckles et al. 1993). At the point when periphyton amassing rates are high, leaf turnover is no more a successful instrument for keeping up low periphyton loads. Estimations of periphyton light transmission must be made in place of submerged periphyton groups (Vermaat & Hootsmans 1994, Brush & Nixon 2002, Stankelis et al. 2003, Drake et al. 2003).

Dissolved oxygen: Satisfactory broke up oxygen is crucial for the survival of amphibian life forms and along these lines is a critical variable in the evaluation and observation of water quality (Morgan et al. 2006). Oxygen focus in streams can differ actually over diel and regular time scales, extensive changes in oxygen fixation frequently demonstrate inordinate productivity coming about because of supplement advancement (Walling & Webb 1992). As algal biomass builds, breath amid evening can drain oxygen fixation to qualities that murder defenceless living beings and result in for the most part weakened biotic honesty (Portielje & Lijklema 1995). In eutrophic streams and waterways, broke down oxygen can go from supersaturated amid light to almost anoxic during the evening. Less gainful and probably less hindered, streams are by and large portrayed by broke up oxygen, focuses close immersion with some moderate diurnal change brought about by temperature (Walling & Webb 1992).

Current velocity: The significance of water speed as an essential controller of the conveyance and structure of photosynthetic life forms in streams is generally perceived (Biggs 1995, 1996a). Water speed is additionally constricted by periphyton. Stream macrophytes reduce the velocity near the bed and within the mass of plants, the magnitude of the effect depends greatly upon the growth form and architecture of the plants. Sand-Jensen & Mebus (1996) showed that plants with large leaf areas on bushy shoots reduce water velocity more than plants with streamlined, strap-like leaves. The relevance of these previous approaches to understanding the effects of different species of periphyton and macrophytes on water velocity in streams across mm to dm scales has not yet been demonstrated (Walterk & Biggs 2002).

pH: The role of pH in organizing periphyton groups has seldom been inspected explicitly in peatlands (van Dam et al. 1981, Bellemarks & van Dam 1992). The impact of pH on oceanic frameworks or algal groups have for the most part tended to the impact of anthropogenic fermentation of surface water (Planas 1996). The effect of fermentation on algal groups has demonstrated some broad patterns. Fermentation regularly bring about diminished species richness (Muller 1980, Schindler et al. 1985, Turner 1991). Generally, addition to algal biomass has been accounted to increments in response to acidification (Muller 1980) more often than because of the blossoms of filamentous green growth. The other way of effect on the pH range is alkalinization. Neutralization can regularly switch the adjustments in the algal group which came about because of fermentation, again especially in the filamentous green algae. For example, several balance concentrates have found that *Mougeotia* is definitely reduced when pH is increased by means of liming from about pH 5 (Fairchild & Sherman 1992).

Nutrients: Phosphorus and nitrogen are nutrients that are essential for aquatic plant and algal growth. Most waters naturally contain enough of these nutrients to support native aquatic life. However, an overabundance of these nutrients can overstimulate plant and algal growth creating water quality problems. Phosphorus and nitrogen are supplements that are crucial for plant and green growth development. Most waters normally contain enough of these supplements to bolster aquatic life. Inordinate macrophytic vegetation is characteristic of the eutrophication status of any water body (Kaur & Singh 2012). Supplement improvement and eutrophication are connected to an assortment of human exercises that can diminish water quality, for example, horticulture, sewage release and urbanization (Biggs 2000, Dodds & Welch 2000). Periphyton is a great wellspring of value nourishment for supplied fish (Whal 1989). Periphyton is shaped after taking a settling example, which can be separated into four stages: (i) adsorption of broken down natural mixes, i.e. macromolecules that append to submersed surfaces, being an unconstrained physico-chemical process; (ii) bacterial settling-after colonization, microscopic organisms begin to deliver extracellular polymeric substances (EPS), that ensure them against predators, and expansion of their imperviousness to the radiation and drying out; (iii) colonization by eukaryotic unicellular microorganisms, for the most part protozoan, microalgae and cyanobacteria and (iv) settling of eukaryotic multicellular organisms. Periphyton is the essential nourishment hotspot for little fish, crawfish, grass shrimp and other little shoppers at the base of the sustenance web. In this way, understanding changes in periphyton is basic to decide foundations for modifications in groups of appealing megafauna (i.e., huge fish, wading winged creatures, gators). The Everglades is characterized as an oligotrophic system whereby fauna and flora have adapted to extremely low levels of nutrients (Entry & Gottlieb 2014). Minute increase in nutrient availability can alter the form and function of the entire ecosystem (Gaiser et al. 2011). Nutrient loaded water, originating from urban and agricultural sources, ultimately flows into the Everglades; this influx of nutrients disrupts the historical balance of the ecosystem, including the conversion of sawgrass stands into cattail and the obliteration of periphyton mats (Entry & Gottlieb 2014).

Phosphorus: In freshwater frameworks, expanded inputs of phosphorus are of specific concern, since it usually is the constraining supplement for productivity in freshwater biological communities. Phosphorus stacking to streams can build the biomass of periphyton, macroalgae, and sestonic green growth, as measured by chl-*a* (Welch et al. 1989, Van Nieuwenhuyse & Jones 1996, Dodds et al. 1998). The total phosphorus (TP) of periphyton tissue is one of the best measures of P burden history (McCormick & Stevenson 1998). While increments in water and also soil P are just distinguishable following quite a while of improved P stacking (on account of rapid microbial and physical uptake), impacts upon periphyton TP focus are quick (Gaiser et al. 2004a,b). Extensive scale misfortunes of periphyton all through the framework have happened because of intemperate P advancement from waterways (Gaiser et al. 2006) and these misfortunes have had falling impacts all through the Everglades ecosystem (Gaiser et al. 2005). Thus, periphyton TP focus and associated variables (i.e., calcite content, species piece) are routinely observed in many Everglades programs. Researchers have demonstrated a strong correlation between total phosphorus inputs and algal biomass in lakes (Anderson et al. 2002).

Nitrogen: Protection and remediation of these resources are, therefore, contingent on a better understanding of the quantitative relationship between algae and inorganic nutrients (Rier & Stevenson 2006). The effect of fire on the nitrogen (N) cycle is highly important because N, like phosphorus (P), is often a limiting nutrient for primary productivity (Liao et al. 2013). Nutrient enrichment can significantly alter algal community composition, biomass and productivity (Stockner & Shortreed 1978, Grimm & Fisher 1986, Pringle 1990), but autogenic changes associated with periphyton development may feed back to influence nutrient availability and mitigate enrichment effects (Bothwell 1989, Pringle 1990). Sycamore Creek experiences seasonal, often intense spates in early spring and late summer separated by extended periods of stable, low discharge during which algal and invertebrate biomass rapidly increases to high levels (Fisher et al. 1982, Grimm & Fisher 1989).

Biomass: Changes in periphytic groups have been connected with an assortment of anthropogenic effects including land use and occupation (Elsdon & Limburg 2008), supplement enhancement, and the accessibility of light (Guasch & Sabater 1998). These components can act in conjunction to increment or abatement of periphytic biomass in mainland seagoing biological systems. Periphyton biomass is associated with stream supplement focuses (Dodds et al. 2002), albeit nearly little is thought about periphyton stoichiometry in respect to basic natural inclinations (Sterner & Elser 2002, Cross et al. 2005).

Chlorophyll-*a*: Chlorophyll-*a* is an omnipresent photosynthetic pigment present in all eukaryotic (green growth) and prokaryotic (cyanobacteria) phytoplankton life forms. Chl-*a* fluorescence has turned into an undeniably imperative device for the evaluation of both biomass and photosynthetic action of phytoplankton with multiwavelength fluorometers that permit *in vivo* and/or *in situ* taxonomic distinguishing proof (Falkowski & Raven 1997). These gatherings have particular extra shades which ingest light effectively in various scopes of the noticeable light range (Millie et al. 2002). When they assimilate a photon, these colours get to be energized and they exchange their excitation vitality from shade to shade to the Chl-*a*, the terminal acceptor of the excitation exchange channel, which radiate fluorescence looked into in (Krause & Weis 1991). Two gadgets, the Phyto-PAM (Heinz Walz, Germany) and the Fluoroprobe (BBE Moldaenke, Germany) (Beutler et al. 2002), are at present accessible. They have four to five excitation wavelengths and can recognize from three to four ghastly gatherings (green growth, cyanobacteria, 'chestnut microalgae' (chiefly diatoms and dinoflagellates) and a 'blended gathering' (cryptophytes)). Late methodologies have been created to refine the separation between the two phantom gatherings of cyanobacteria (blue and red) and the cryptophytes (Beutler et al. 2002, 2003).

METHODS FOR ASSESSING PERIPHYTON PRODUCTION

It is an analytical procedure to evaluate periphyton production under natural conditions, which can be recognized by change in species synthesis, cell thickness, fiery remains free dry weight, chlorophyll and catalyst movement. Periphyton gathering, including the hardware and supplies required for examining, technique description, sample safeguarding and taking care of and research centre quality control for testing recognizable proof for periphyton strategies outline (PMS 2006).

CONCLUSION

Periphyton and its growth are highly influenced by environmental factors in water. There is a reduction in yield, increased growth, loss of capacity to water quality and increased susceptibility to environmental stress which causes numerous harmful effects on water quality.

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