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Algae the Bioindicator for Sustainable Environment: A Review

Review Article

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Abstract

The wide and varied development in the application of algae has overcome the environmental challenges and boosted up the confidence in achieving sustainability. The term sustainability refers to the overall productive improvements of an environment that includes a variety of dynamic structures and their regulations. The rapid population growth and rapid civilization have led to the exhaustion of nature and its vibrant resources. However, advances in phycology aimed research and related fields have shown a productive hope on the track to green transformation and the preservation of sustainable environments. Because it can replace multiple domestic necessities and action of human beings, algae can be a promising agent for use in developmental activities. This review discusses the broad range of possibilities for using algae as in sustainable development.

Keywords: Algae; Bioindicator; Sustainable; Water Quality; Biofuel

Introduction

Algae - a plant body deprived of root, leaves and stem. It executes the photosynthetic activity, has found across prokaryotic to the eukaryotic form.[1] The algae show diversified territories from extreme habitat to most favourable enclosing such as, freshwater lakes to saline oceans to flowing streams into still ponds, various soil structure of sturdy rocks, farthest points like warmest temperature (deserts) to cold temperature (Himalayas) and evenly observed having mutual association with animals and plants covering 70% of earth with reference to its ecological scattering.[2] Taxonomic algal classification observed so ambiguous, because of their extensive characteristics, from blue - green algae to oceanic giant Kelps.

Algae are unicellular, microscopic, colonial and free-floating photoautotrophic organisms that grow in aquatic nature, whose movement relatively dependent upon water currents. Algae act as considerable feature in biosynthesizing organic matter in water body which directly or indirectly serves as food to all the living organisms in it. Thus, the algae community is regarded as primary producers in the food web, ensuring ecological balance in the aquatic environment.

Within a phases of three decades, the application of algae amazingly extended with the introduction of advanced techniques and skills. Thus, algae have been explored for bioindicator for water quality, bioremediation of waste water bodies and agricultural fields. Also algae become a major source of sustainable energy and biofuel production and etc., thiscomprehend the algal ability.

Algae as Water Quality or Pollution Indicator

Algae (phytoplankton) have been used for successful examination of water contamination and thus counted useful indicator of water property and trophic status of aquatic ecosystem owing to their small life duration and speedy population growth.

As extensively studied aquatic habitats and their biota have been widely examined since the early 19th century, and curiosity has raised swiftly in latest years by reason of the expanding request intended for water and fish, and the necessity for succeeding the water of reliable quality. Thus, a number of analyses have been supervised globally to assess the water quality of different water bodies with help of these algal parameter.

Kolkwitz and Marrson (1908) are the first who announced the idea of bioindicator of pollution in their saprobic practice and also showed the relativeness of water organisms towards extent of water pollution.[3] Hutchinson (1957) specified that temperature is vital in manipulating both the quantity and quality of plankton flora.[4] Dakshini and Gupta (1979) conducted a study on physicochemical properties of water of three lakes situated around state Delhi. According to them, organically loaded waters can be identified by presence of *Microcystis* algae.[5] Tripathy *et al*. (1989) recorded the Phytoplanktons that indicated the water pollution of Ganga river of Varanasi.[6] Mittal and Sengar (1991) stated that water phytoplankton could be used as indicator to explore the physicochemical status of any water body.[7] Diatoms have been utilized broadly in water quality checking as stated by Round (1991).[8] They exist in a wide extend of biological condition, colonizing nearly in all appropriate environments, they can in this way give different markers of natural change.[9] Gaur (1997) stated that species of *Microcystis* utmost usually occurred in eutrophic water of India.[10] Ray *et al*. (2004) studied the probable appliance value of Diatoms as pointers of water quality.[11] Extremely high photosynthetic primary productivity in a water body with a maximum pH 9.52 was noted by Lopez-Archilla *et al*. (2004) in Santa Olall's (Spain) and recorded that many of phytoplankton gave their presence in maximum pH and those includes numerous sp. of diatoms, green algal and euglenoids and some from order Nostacales and Chroococales (Cyanobacteria). Also, a bloom of *Aphanothece clathrata* was observed by them.[12]Reduce pH below the 5.0 in rivers and rise in algal biomass and primary productivity reported by Dora *et al.* (2010).[13] Stokes *et al.* (1989) observed the reduction in abundance of diatoms and blue-green species as when pH drops.[14]

Fathi and Flower (2005) investigated lake Qarun (Egypt) to identify lake water quality variables and phytoplankton with respect to seasonal variations and they observed the most diverse group of algae as Bacillariophyceae with 23 species, Chlorophyceae (16 species), Cyanophyceae (8 species) and one species each in Chrysophyceae and Dinophyceae. During their study they also showed the occurrence of phytoplankton species that indicated a tendency towards eutrophic nature of lake.[15]

Palmer (1969) made the first effort to identify and make a checklist of genera and species of algae tolerant to organic pollution. He showed that the algal genera like *Oscillatoria, Euglena, Scenedesmus, Navicula, Chlamydomonas, Stigeoclonium, Nitzschia* and *Ankistrodesmus* are the utmost tolerant species observed in organically pollutants containing waters.[16] Algae is a bioindicator of organic contaminants in twenty lakes of Karnataka observed by Hosmani.[17]

Water quality and algal community of Haranbaree dam of Maharashtra as assessed by Nandhan and Aher (2005) recorded pollution tolerant genera from *Navicula, Oscillatoria and Euglena* and quantitatively abundance of cyanobacteria.[18] Tiwari and Chauhan (2006) reported total 73 algal species and showed that genera like *Oscillaloria, Nitzschia* and *Cymbella* were known to be sign of polluted water of Kitham lake, Agra.[19] Ghavzan *et al*. (2006) observed the higher values of analyzed physicochemical parameters and found the dominance of blue-green algae and diatoms, which showed the stressful and increased eutrophication owing to influx of untreated household sewage and trashes of industry in river. [20] Muthukumar *et al*. (2007) investigated limnology and cyanobacterial diversity of freshwater of 5 different ponds located at Thanjavur, Tamil Nadu during summer month and they compared the resultant variations among 5 ponds and identified 39 species from 20 genera of Cyanobacteria. Enormous bloom of *Microcystis aeruginosa* was also noticed by them and stated that its presence had a great effect in lowering the other cyanobacterial inhabitants.[21] Rich phytoplankton diversity of about 47 genera and dominancy of diatom had been noticed by Kavitha and Ragini (2007) at sacred groove of Kanyakumari, fresh water ecosystem, (district-south Tamil Nadu). They also reported 11 pollution indicating flora. [22] Sudeep and Hosmani (2007) stated that pollution level in a lake can be determined by using various algal biodiversity indices.[23] Declined water quality and increasing trend towards eutrophication with a dominant bloom of *Microcystis aeruginosa* was observed by Vijayveriya (2008) at lake Udaisagar (Rajasthan).[24] Kumar *et al*. (2008) studied physicochemical properties and diatom indicators of trophic status of Kishore Sagar, Rajasthan.[25]

Due to diatoms having the ability to tolerate various environmental ranges and variables like pH, suspended sediment flow regime, nutrient concentration and different human disturbances, they are used widely in environment monitoring and assessment (Laksar and Gupta, 2009).[26] Chellappa *et al*. (2009) founded abundancy of toxic Cyanobacteria *Planktothrix agardhii* and *Microcystis aeruginosa,* while studying phytoplankton community in three areas of reservoir in Brazil.[27] According to Bhosale *et al*. (2010) *Spirulina* species can be used as sign of sewage pollution.[28] Atici and Obali (2010) determined that pennate diatoms species of *Cymbella* and *Nitzschia* were adjustable to environment aspects.[29] Mishra *et al*. (2010) studied reservoirs of Uttrakhand and showed the common occurrence and abundancy of *Microsystis* species and also observed the medium level of productivity of reservoir.[30] Basavarajappa *et al.* (2011) formulated an effort to evaluate the indicators of fresh water- the Diatoms, from some lakes of Mysore (India).[31] Patil *et al*. (2012) made an attempt to investigate Shivaji University lakes of Kolhapur, India, to find out the impact of physicochemical characteristics on phytoplankton communities and observed the presence of *Microcystis sp*. in their studied lakes.[32] Atici and Ahiska (2005) (Ankara stream), in their research found that the *Spirulina* and *Oscillatoria sp*. were adjusted to pollution.[33]

Thakur *et al*. (2013) observed *Microcystis aeruginosa* dominancy in all season and also showed the common occurrence of *Synedra* species, signal of eutrophication in their studied lake Rewalsar and Kuntbhyog, Himachal Pradesh (India).[34] Atici and Alas (2012) examined tropic position of Mamasin lake, Turkey and showed that *Scendesmus* and *Chorella* species were signals of pollution.[35] Ishaq *et al.* (2013) observed dominant group Bacillariophyceae with *Fragillaria* genera and other diatoms throughout their entire studied period.[36]

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Chopra *et al*. (2013) investigated 3 fresh water lentic aquatic bodies and observed the alkaline water of lake and showed the presence of Cyanophyceae, especially *Microcystis* species as a sign of eutrophic water body.[37] Kotadiya and Mulia (2014) investigated total 20 algal genera out of which 7 were pollution conforming phytoplankton was revealed at their studied Ghuma Lake in Ahmedabad (Gujarat state).[38]

Singh (2015) studied a seasonal study of phytoplankton (pollution-indicator) diversity of Gomti river, Lucknow, (India). Several genera belonging to Chlorophyceae, Bacilloariophycea, Myxophyceae were recorded by him. He showed that high activity of diatom is the signal of organic pollution in the river and also stated that presence of species of *Oscillatoria* at polluted locations can be used as trace of organic pollution in the water bodies.[39] The water quality and plant plankton range of canal of river Ganga in India were investigated by Matta *et al*. (2015) in which they observed mostly diatoms species during summer months due to high pollution load and anthropogenic activities.[40] Sasikala *et al.* (2017) conducted a study on phytoplankton in Varaha reservoir, Vishakhapatnam and reported the total of 10 phytoplankton species of Chlorophyceae, 3 of Cyanophyceae and 2 of Bacillariophyceae with a noticeable bloom of *Microcystis aeruginosa*.[41] Thus, algae assessment became a useful scientific study in envisaging the degree of pollutant scale, formerly the effect of pollution starts in water bodies. Water bodies contaminated with heavy metals and toxic metallic components such as cadmium, lead, and mercury can be identified quickly by observing the development of *Chlamydomonas reinhardtii.*[42]Direct correlation of *Stigeoclonium* growth and high concentration of metals in river have been noticed byReddy and Venkateswarlu (1985).[43] Sudhakar et al. (1991) revealed that algae *Cladophora* is very sensitive to heavy metals. [44]

Algae in Bioremediation of Pesticide

The usage of pesticides is growing daily with increased urbanization and agricultural strengthening. Pesticideusually include together activeand inert type of componets. The one with active compound focus and damages the pest, whereas the inert component lifts the efficacy of active components. [45] Pesticide have great potential but excessiveness use of pesticides generated a serious alarms about environmental and human health. Pesticides may be having its effect on air, penetrate into the soil or could be ingested by living organism. Pesticides that change the actions of soil microbes are expected to have an adverse impact on soil nutritious properties and thus, have serious environmental consequences. [46]

In the case of pesticide contamination, bioremediation may be a viable option. It is suggested as a cost-effective and dependable option. Microalgae are a naturally appearing biotic agent that has been illustrated as one of the furthermost effective pollution control practices for removing pesticide impurities from agricultural run-off and polluted or contaminate water sewages. Actually,balanced attempt like bioremediation might greatly enhance environmental quality and it must be established by highlighting the metabolic functioning and ability of microalgae.

Microalgae were involved as a well-known worthy for the decontamination of such kind of unsafe pollutants. Sustainable appliance and remediation approaches of pesticides toxins in the field of farming by microalgae from the former studies, and latest advancements were increased enormously and helping in setting sustainable resources.Hence, removing organic pollutantsbymicroalgae involves mechanisms of bioaccumulation, biodegradation and biosorption. [47]

Microalgae because of their higher degree of biosorption abilities are very well suited for contamination removal. The structure of cell wall of microalgae such as carbohydrate facilitates the biosorption of harmful pollutants.[48,49] The special characteristic of microalgae is exhibits in its cell wall, made up of sulphated polysaccharide which assist in increasing efficacy of pesticide adsorption from the pollutant water. Hussein et al. in 2012 noted that biosorption by *Chlorella vulgaris* in elimination pesticide such as carbofuran, simazine and dimethoate.[50] It is also noted in various studies that factors like structure and molecular size have an effect on biosorption. Thus, bigger the algal cell particle, the better the surface offered for pesticide to bio absorbed. [51] Henceforth, microalgae can excellentlyeradicated pesticides via biosorption.

Toxic compounds can also be accumulated by microalgae through bioaccumulationability. It is determined by the lipid content of algal cells, which is influenced by growth conditions and cell distribution.[52,53] Active biosorption is a metabolism-dependent process that results in bioaccumulation. It is stated as the process by which pollutants are transferred further into the inside of active cells. This procedure is powered by energy, as the microalgae must transfer pesticide compounds across the biological membranes for metabolization and accumulation. [54] Further, Pesticide biodegradation by microalgae into simpler compounds serves as a nutritional source to support microalgae growth.[55] The enzymatic action of several enzymes such as phosphatase, hydrolase, transferase, esterase and oxidoreductases is required for pesticide biodegradation.[56,57]

Sustainable Energy and Algal Biofuel

As the world's population grows, so do the world's energy demands. To fully - fill the energy stresses with existing sources is a task that is completely unacceptable. Because of the unfavourable developments associated with using fossil fuels. As a result, alternative energy sources must be identified.

Three generation sources of fuel have been acknowledged, but they have failed to provide sustainable development. Algal biomass energy is the most viable alternative to bio fossil fuels. [58] This, in turn, contributes to full fill the energy demand-supply gap. As first and second generation biofuel sources compete with agriculture and food supply for a growing population. [59] Algal biofuel has become the initial focus of algal research, with broad - based research now being conducted. Hence, algae have turn into the latest possible source being aimed for biofuel production.

The process of manufacturing biofuel from algal fatty acid is non-hazardous and highly recyclable. Microalgae can reproduce at rates up to fifty times faster than the increasing land-dwelling crop. They will accomplish their growth period in a few days via photosynthesis process, which converts solar energy into energy. They require a

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higher photon change efficiency, it is approximately 3–8 percent compared to 0.5 percent for terrestrial plants. They can grow almost anywhere, in water, wastewater, seawater, or non-arable land. When compared to other sustainable energy sources such as geothermal, solar, and wind etc. algal have more potential towards production of biofuel with no usage of higher amount of water or larger fertile type of land.

Phycoremediation of waste water by algae

Water quality is directly concern in the twenty-first century, with the water shortages. Water quality degradation, whether caused by anthropogenic sources like pollution, overexploitation of resources or natural events like global warming risky climatic events, frequently has severe consequences for ecosystems, public health, and wealth creation, adversely affecting society and the environment.[60] The improvement of quality of water is a critical concern shown in the agenda 2030 as well as on Sustainable Development Goals, recognises the significance of potable water for society's long-term development and, thus, the need to address this issue globally. Algae play a key role in restoring the environment's original state, which has been significantly changed by various pollutants.

Phycoremediation is a process that uses algae to eliminate contaminates or transform them into harmless forms. Algae are extremely adaptable in nature. Based on availability of substrate and light, they can develop heterotrophically, autotrophically, or mixotrophically. This increases its chances of survival in harsh environments.[61] Many pollutants can be absorbed by microalgae during photosynthesis in water.

The release of improperly treated effluents into lakes,rivers and coastal waters introduces an overabundance of chemical compounds into the aquatic environment, which can have an immediate impact on water organisms by activating hazardous effects, and an indirect impact on altering some physicochemical properties (e.g., Dissolved oxygen, pH, and nutrient levels). Algae (*Chlorella* sp.) has been confirmed for pre-sewage treatment, offering greater insight in treatment plants and assisting with multiple commitments such as effective metal ions (especially Ca, Al, Fe, Mg and Mn)removal and rich biomass growth for further biofuel extraction.[62]

Biological treatment technologies related to the implementation of sustainable treatment methods could be one possible solution. Microalgae cultivation is frequently used in biological treatments. Algae likewise *Ulva & Monostroma sp*. are proved to be applicable in reducing the content of nitrogen & Phosphorus from drainage waste water from numerous sources. [63] Literature has highlighted microalgae's capacity to delete nutrients[64], metals [65],pharmaceutical drugs[66] or pathogenic microbes [67] from the medium. Phycoremediation is the use of microalgae to eliminate toxic chemicals from municipal wastewater or carbon dioxide from the waste air altogether with biomass production. [68] The basic mechanism underlying this procedure is inherent in algal metabolism. However, the removal of organic pollutants will vary depending on the microalgae used and the characteristics of the effluents. Thus, microalgae created technology has many opportunities in environmental and product development applications.

Algae in Serving as Feedstock

With the changing climatic situation and other increasing factors like greenhouse gases, agricultural productivity is assumed to be slow down. Thus, the economically and another possible animals feedstock explores have created its solutions towards algae. Due to its high protein content, many algae have proven to be important animal feeds. The nutritional profile of algae is adorned with essential human dietary supplements such as vitamins, amino acids, proteins, lipids, polyunsaturated fatty acids, carbohydrates and antioxidants. These have been reported by researchers in many algae.[69,70] Reports around the world show positive signs of using seaweed as feed for cattle, and the results show promising in some experiments. For example, chlorella has been tested for chicken development and has demonstrated its ability to supplement nutrition. [71]Today, the aquaculture industry makes widespread use of algae as co-cultured organisms, increasing the productivity of aquaculture through the association of aquaculture systems. [72]Spirulina genus have been observed as a chief feed in the Japanese fish farming industry. [73] At the same time, the future scale of biomass extraction from biofuel has promised future raw material availability for feedstock for animals.

Conclusion

Algae have demonstrated their ability to become convincing bio prospective tools. However, there is an urgent need for centred research in the fields of phycology and implemented phycology in order to investigate the possibilities of the microalgae resource. The algal community has solutions for a variety of long-term challenges, such as biofuels production, polluted soil and water remedial action, bioremediation of pesticide from agricultural fields, and so on. This review effectively explained the numerous opportunities to explorealgal resources in the future.

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