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The Role of Algae in Sustainable Environment: A Review

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ABSTRACT: The diverse development in the employment of algae to conquer the environmental snags have stimulated the assurance of achieving the sustainability. The word sustainability indicates the overall constructive improvements of an environ that encompasses a plentiful dynamic and their regulations. The hasty growth of the population and rapid civilization has led mankind to the exhaustive exploitation of nature and its vibrant resources. However, today humans have realized the catastrophes instigated because of their preceding errors and have already been facing future sustenance challenges. Today, it has turned out to be a challenging task to discover and to develop an eco-friendly, cost-effective, and cutting-edge strategies to encounter the current sustainability glitches like, sustainable agriculture solutions, feedstock crisis, pollution, carbon neutrality, industrial effluents and waste water treatment, energy crisis, and xenobiotic components contaminated the natural ecosystem.
Advancement in the field of phycology research and allied areas has shown a positive hope on the way to green conversion and retaining sustainable environments. Algae can be a candid agent for employing in the developmental activities, as it can replace various domestic needs and deeds of man. This review discusses the wide spectrum opportunities of using algae for sustainability ground rules.

Key words: Algae, Environment, Agriculture, Bio indicator, Pollution, Waste water.

INTRODUCTION

Algae - a plant without stem, root and leaves which performs the photosynthetic activity, has spread across unicellular prokaryotic to the multicellular eukaryotic family [1]. The Chinese, around 2000 years ago explored and knew the applications and importance of “Nostoc”, an alga hence used in daily activities [2]. The omnipresent algae show varied habitats from extreme conditions to most favorable surroundings such as, saline oceans to freshwater lakes, running streams into stagnant ponds, different soil composition of sturdy rocks, extremities like freezing temperatures (Himalayas) to hottest temperatures (deserts) and even found having symbiotic association with plants and animals [3] covering 70% of earth with reference to its ecological distribution [4]. The taxonomic classification of algae is ambiguous, due to their widespread characteristics, from microscopic blue-green algae to marine giant algae Kelps. Because, blue-green algae are linked to a gram-negative bacterial community, whereas macroscopic marine giant algae kelps share the features with higher plants. According to the Radmer and Parker [5].

Algae to be grouped and named according to their molecular data as, *Cyanophyceae, Euglenophyceae Rhodophycea, Plantae (Chlorophyta), Alveolates (Dinophyceae), Stramenopiles (heterokont). Chlorarachniophyceae, Cryptophyceae, Haptophyceae*. The studies based on the morphological structures, microscopic identification, and the phyco-chemical analysis, the advent of new biotechnological tools, and molecular techniques have made, grouping of algae even easier to understand [6]. Within a period of three decades, the application of algae remarkably expanded with the introduction of modern skills and techniques, and they have been investigated for nutrition supplement as a single cell protein, later commercial products like pigments, dyes, nutrient supplements such as vitamins, proteins, *etc.,* encompass the algal competency [2, 7]. The widespread industrialization, cumulative urbanization, pervasive deforestation, environmental pollution, growing population, and greedy human activities, *etc.,* have resulted global warming or environmental catastrophe. The rise in a new phase of industrial developments [8], ensued hike in fuel demand [9]. Undemanding flow of petroleum-based fuels accelerated from the source to the point with which environment distressed extensively. Along with air pollution, solid wastes and liquid effluents been added chaotically to the environment, by water pollution, soil pollution, and extinction of various natural habitats have been reported [10]. The increase in the on-road vehicle number which either uses petrol or diesel as an energy source, emits CO_2, CO, NO_x, particulate matter and other unused hydrocarbons in the atmosphere and contributes their part in pollution. An increase in the need has turned into greed, appealing mankind for non-scientific, hazardous accomplishments to carry which has resulted in the environmental crisis. In order to reform the natural environment, it is not only essential to understand the co-existence of abiotic and biotic factors and their vital role in harmonizing the environment, but also important to ascertain the approaches to achieve the same purpose [11].

As mankind can't restrict abiotic factors of nature, biotic factors are the only resources to play with. It is also factual that, the current methods and management to surmount environment pollution proven to have a negative impact on nature, there is a requirement of new, advanced, eco-friendly, economically feasible technologies and management [12]. The complete genome sequencing of *Cyanidio schyzonmerolae, Thalassiosira pseudonana, Chlamydomonas reinhardtii, Volvoxcarteri* and *Ostreococcus tauri* has been completed successfully [13]. Many algal genomes sequencing efforts are in progress. The extensive applications of algae in various fields, gaining more importance and along with these genomic level study efforts, expressed sequence tags of algae, mitochondria and chloroplast sequencing are also in the pipeline of algal biotechnology research. The genetic transformation studies have been carried successfully in approximately 35 different algal species with gene transform techniques such as micro-particle bombardment, particle gun transformation, gene gun transformation successfully into algal cells in spite of the cell wall type [1].

Astraxanthin one of the natural oxidants occurs in *Haematococcus pluvialis* whose productivity is enhanced by the biolistic transformation with the identification of the gene responsible for the production of carotenoids which is modified with the point mutation and stable transformation is achieved [14]. This proves the efficiency of algal biotechnology in enhancing and obtaining the desired goods and service by the algae for sustainable welfare for future scenario. The *Chlamydomonas reinhardtii*, species have been tested for the expression of therapeutic proteins and their algal chloroplasts have given more than 50% expression of desired proteins [15]. Due to the spread of biotechnology across the algal genetics, the algal chloroplasts have attracted the researchers for expressing genome in chloroplast as an effective expressing platform. The cutting-edge proficiency of genome editing in future employ the algae by amending its genetics for the expression of desired characteristics for viable products [16, 17]. However, with the improved understanding and the extensive ground work it is possible to obtain the expected algal productivity. Generally, it can be divided into two types based on the purpose and application:

Transgenic algal biotechnology:
Transgenic defines the subsequent gene transfer, gene manipulation with genetic engineering skills. Hence, the genetic engineering approach in manipulating the algal genome for the amplification of algal productivity can be defined as transgenic algal biotechnology. With the advent of the recombinant DNA techniques one can create algae with new characteristics. Hence, there is a huge opportunity to work with the algae for sustainable services to the society in all the possible directions. Transgenic algal biotechnology can troubleshoot the present complications associated with algal biomass utilization and biomass enhancement and productivity complexities etc.

Non-transgenic algal biotechnology:
This can simply be put as the biotechnology of the algae, wherein there is no genetic manipulation carried only the techniques can be employed for the assessment of the algal productivity. This includes the conventional method of algal handling and obtaining the useful productivity from algae. Hence, the commercial products so far obtained are of non-transgenic algal products [1].

Algae in Agriculture:
In the customary methods of agriculture, the addition of synthetic fertilizers, into the soil environment and the addition of continuous chemical herbicide resistant, pest resistant modules have adversely affected the soil microenvironment that in turn play a decisive role of a drop in the crop yield [18]. However, the naturally existing soil microorganisms can help in maintaining the soil health such as *cyanobacteria* an alga which can fix the atmospheric nitrogen in the soil and supports in the growth of plant [19]. Due to the external addition of synthetic chemicals, it is found that the growth and fixing ability of *cyanobacteria* is reduced. This can be a major risk to the soil biodiversity as well as crop productivity. With the biotechnological tool in rice field the nitrogen fixing ability of the crop can be enhanced by the presence of *cyanobacteria* in the crop environment and pest resisting cyanobacteria have the capability of nitrogen fixation in the presence of synthetic nitrogen source [20]. Hence, with the ethical consent, genetic engineering or mutational studies on these *cyanobacteria* can be a possible sustainable way to better agriculture. With the advantage of marker selection in case of plant genetic studies the herbicide resistant algae can become a crucial player, when it comes to some of the hazardous pesticides, herbicides, which reside in the environment for a long time even after several years of its spread over. Such

residues may pose masked risk to the human health as well as the environment [21]. Algal strains with their ability to degrade these residues left over in the agricultural runoff, soil can be utilized for the degradation of these xenobiotic chemicals. Lindane is one such an insecticide used since long which is a hazard to in human health is degraded successfully with the help of *Cynobacteria* strains *viz., Anabaena* sp. and *Nostoc ellipsosoru*. The following strains have been genetically manipulated in such a way that it should degrade insecticide effectively. For which the operon for dechlorination of lindane was identified and successfully manipulated by incorporating the lindane dechlorination operon found in a bacterium [20]. It is interesting to use these two algal strains because they are cost effective in production and can be easily grown and also, they utilize atmospheric carbon for their activities [20]. On other side, biomass of algal species like *Phymatolithon* spp. *Ecklonia* spp., *Ascophyllumnodosum* have been used as fertilizer in horticulture [22].

Algae as a feedstock:

With the increased greenhouse gas emissions, fluctuations in the climatic conditions occurred due to which agricultural productivity is expected to hamper [23]. This in turn curtailing the supply of feedstock for the animals in future. Thus, the alternative and economically feasible animal feedstock searches have found its solutions in algae. Various algae have been reported for their rich content of protein this maid importance over the animal feed as protein is an expensive supplement for the animal feed [24]. The nutrient profile of algae is ornamented with essential important human supplements such as, Carotenoid, vitamins, Amino acids, proteins, lipids, polyunsaturated fatty acids, carbohydrates, antioxidants reported in numerous algae by several researchers [25, 26, 27, 28, 29, 30]. Reports across the world have shown a positive sign for using algae as animal feed stock and outputs shown promising in several experiments such as, *chlorella* was tested for the developments of chicks and proved its nutrient supplementation ability [31]. Certain microalgae acted immensely not only on the physiological supplementations but have effectively supported the growth and health of the organs in the animals fed by them [32]. Today aqua culture industry extensively employing the algae as a co culture organism and enhancing the aqua culture productivity by associating the life system in water [33]. Therefore, with the animal feedstock the aquaculture needs can also be fulfilled. Along with which the future scope of biomass enhancement for the biofuel purpose promised the availability of feedstock in the future. Genus such as *Arthrospera, Tetraselmis, Chlorella, Dunaliella, Haematococcus, Nannochloropsis, Nitzschia, Navicula, Amphora, Crypthecodinium, etc.,* have been reported as potential feedstock in case of aquaculture facilities [34]. However, overall replacement of the traditional crops with the algae is not yet successfully implemented, because of the stability and low yield of biomass. According to the earlier and current reports the leftover biomass obtained after biofuel extraction methods can be used for the purpose of feedstock in the case of chicken, cow, and other animals because of the deflated nature of leftover material [35].

Bio-indicator of environment fitness:

Environmental health assessment is also a vital concern today and there is a need of effective assessment strategies needs to be designed because assessing environment fitness is laborious and time consuming by the virtue of present methods [36, 37]. Algae growing in various soils can be a feasible sign of the soil health and soil fertility [38]. Most of the algae grown on top soil and act as an indicator of contaminated soil in agriculture land. In an experiment the effect of hydrazine on the photosynthetic activity and algal population of soil is estimated and proved that, algae can be utilized as a strong agent for identifying the xenobiotic contamination in soil [39].

Water quality can be assessed by the growth of phytoplankton's, which grow on polluted water bodies [40]. Water bodies polluted with the heavy metals, toxic metal components such as cadmium, lead and mercury can be quickly identified by the observation of the growth of *Chlamydomonas reinhardtii* [41, 42]. Organic pollution of water in reservoirs, and large water bodies results in the degradation of water quality that is assessed and evaluated by the use of diatoms [43]. Eco-toxicological studies, toxicity level assessment in case of water bodies and soil may utilize diatoms, algae for effective risk assessment for a sustainable environment.

Algae for carbon neutrality:

In the biotechnological view point, algae are seen to be a source of biological factory which converts solar energy efficiently into the metabolites [44]. Keeping environmental prospective around, it is evident that the 50% of the photosynthesis on earth is of the algal species which is instrumental in life support [45]. With the increased pollution of atmospheric air quality around the metropolitan cities reduced drastically, as evident national capital of India faced health emergency recently [46]. Hence the need for the carbon sequestration is gaining more mileage in the research community. Multiple route has been existed so far those include, the terrestrial level of carbon sequestration [47] Oceanic sink of CO_2 with the auxiliary backing of algae and phytoplankton's [48, 49]. Physically injecting CO_2 directly into the ocean on the other hand The CO_2 fixation ability of algae is higher than that of the plants and efficiency is about 10-50 times greater than terrestrial plants [50]. Algae can capture atmospheric carbon gases and many algal species have been reported so for viz. *Chlorella* spp. had shown more CO_2 sequestration capabilities and validated [51, 52]. The race way ponds in an open land have a vast exposure and possibilities of capturing atmospheric CO_2 and large-scale photo bioreactors can also enhance the algal productivity by supplementing the required elements. Key models are desirable for air quality improvement in highly polluted environments. Closed race way ponds are developed and tested for the CO_2 fixation efficiency, and 95% of CO_2 fixation was reported in an intermittent operation [53]. Algae can be a sustainable carbon sink for achieving carbon neutrality [54]. For the many developing countries appropriate skills are needed for exploration and utilization.

Algae for waste water treatment:
The industrial insurgence has led the effluent management as a serious concern in present circumstances. The presence of the toxic chemicals, metals, organic and inorganic wastes in the effluents pose a danger to the aquatic life forms. As well as these effluents become a source of spreading health issues [55]. A typical wastewater is composed of various concentrations of organic pollutants and inorganic components such as calcium, magnesium, sulfur, nitrogen, heavy metals *etc.,* [56]. With this activity the water quality drastically reduces and become impractical objects to the common use and drinking purposes [55] Conventional wastewater treatment approaches include physical and chemical way of handling, however they pose a great economic challenges and recyclable troubles on the other hand biological system found commercially feasible at large scale particularly algae have played a major role in it [57]. There are reports justifying algae for potential treatment of agriculture-based waste and the industrial wastes [58, 59]. The algae can be found commonly in most of the effluent water and produce a huge biomass and bloom that can be channelized to treat the waste water [60]. Commonly found Algae in waste waters are *Chlorophytes, Euglinophytes, Chrysophytes and Cynophytes [61]*.

Macro algal species like *Ulva* and *Monostroma* spp. are effective in reduction of the nitrogen and phosphor content in drainage waste flows from various sources [1]. The main advantage in most of the wastewater treatment of industries which themselves provide the supporting nutrients for algal growth, hence in the case of dairy waste effluents algae can grow rich and efficient effluent treatment can be expected and 98% of nutrient removal is achieved [62]. Algal ability to grow naturally in waste waters of municipal waste, industrial waste, farm and agriculture wastewater itself is a major advantage over wastewater treatment [63]. Consortium of different group of algae employed in treating dairy industry waste water resulted in creditable anticipation in a research conducted by the Hena *et al.,* in 2015 [62]. Algae have been experimented for municipal wastewater treatment, provided better insight in treatment plants aided multiple commitments such as efficient removal of metals, rich growth of Biomass for further biofuel extraction [64]. Synergistic combination of algae and bacteria found advantageous in treating wastewater with maximum proficiency in a single day experiment [65].

Sustainable Energy and Algal Biofuel:
With the increasing population, energy demands are also being elevated comprehensively. To full-fill the energy burdens with existing source is a highly unacceptable task. Because of undesirable developments happening with the use of fossil fuels. Hence the alternative energy sources are need to be identified. There are three generation fuel sources conceded, but they failed in providing sustainable development. Algal biofuel is the best alternative to the fossil fuels [66]. This in turn helps in fulfilling the gap between demand and supply of energy needs [67]. As the first- and second-generation biofuels sources are competing with the agricultural land and as well as food supply for the growing population [68]. Algal biofuel has been the first focus in algal research, and wide-angle research being carried already. Economically feasible production of algal biofuel must be established instead of fossil fuel, which is an existing challenge [69]. A program of the U.S. energy department estimated 3000 microalgal species for the production of biofuel [70]. Lipid productivity enhancement can be done with genetic manipulation and another technique is based on the pathway blocking, which leads to the deposition of the required component in large quantity was studied [9]. For the sustainable future the energy sources are also a crucially important and hence the algal biofuel is the best alternative for fissile fuel.

Future Scope: Rich microbial diversity displayed immense potential in fulfilling the needs of mankind.
Especially, the Algae have revealed their Capabilities in becoming the promising bio prospective tools. However there is an immense necessity of focused research in the field of phycology and applied phycology disciplines in order to explore the opportunities of the algal resource. Algal community has solution for the various sustainable Challenges viz. biofuel Production, bio mining and contaminated soil remediation, agriculture and organic residues Cycling, etc. this review successfully explained the multiple opportunities of exploring and exploiting algal resource for the future prospective.

Conflict of Interest: The authors declare no conflict of interest.

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