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REVIEW ARTICLE

ALGAL DIVERSITY IN NEPAL AND ITS APPLICATIONS: CURRENT INSIGHTS AND FUTURE PROSPECTS

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ABSTRACT

Algae are a diverse group of unicellular autotropic microorganisms. It is a free-floating and filament-shaped organism, in which the blade is the main site for photosynthesis. Hence, called a photosynthetic organism. Different types of algae are found in different types of climatic conditions. Algae are found in almost all adverse climates. Due to its vast chemical composition and content of bioactive substances attention of different industries like food, cosmetic pharmaceuticals, nutraceuticals, etc. are caught by it. Algae food products contain a high amount of nutrients, and cosmetic products protect from UV radiation and prevention of rough texture wrinkles of the skin, as they carry out both photosynthesis as well as nitrogen fixation, add organic matter (20 -30kg/ha/year)and maintain texture porosity, the structure of soil and can play an important role for reducing the problem of petrol, diesel. This review has been prepared to shed light on the wide uses of algae as food, fuel, cosmetic product biofertilizer and also to provide knowledge about different types of algae found in different geographical zones of Nepal.

KEYWORDS

Algae, biofuel, seaweeds, unicellular

1. INTRODUCTION

Linnaeus first derived Algae from the Latin word “Alga” which means sea weeds. The study of algae in scientific terms is called Phycology/Algology (Lee, 2008). It is commonly called Children of the Sea. F.E. Fritsch is considered the father of Phycology. Chlorella is the smallest algae and Acetabularia (sea umbrella) is the largest unicellular algae. Poryphyra linearis has the smallest number of chromosomes i.e. n=2, whereas the highest number of chromosomes is found in Netrium digitalis i.e. n=592 Algae are green, aquatic chlorophyll-containing photosynthetic organisms but lacks true stem, and leaves, and roots. About 90% of the total photosynthesis is performed by algae. Algae are simple plants with thallus structures. They are considered as most primitive organisms that absorbs toxic substances.

Algae are chlorophyllous and non-vascular. It is found in every type of soil, on and within other plants, even animals, rocks, on stones, and on diverse climates where a large amount of water is available i.e. both marine and freshwater (Korbitz et al., 1994). In algae, the embryo stage is absent, and non-jacketed gametangia (gametes) are present where all the cells are fertile and meiosis occurs by a zygotic method. They are unicellular, colonical, filamentous, motile, non-motile, dendroid, coccoid, hetertrichous etc. Most of the algae are microscopic, and unicellular and their maximum diameter ranges up to 0.5µ and 60m in length. Algae are covered by mucilages similar to other aquatic plants and protects the plants through decaying of water (Black and Mcginnis, 2006). Moreover, it also protects from epiphytic growth and desiccation (Elnabris, 2000). The cell wall made up of pectin, chitin, algin, and fucondin surrounds each cell. Vacuoles, chloroplast, nucleus, pyrenoids, Golgi bodies, and various types of pigments are embedded inside the cell wall. Starch is the reserved food material in most of the algae, which also varies according to different forms. Reproduction in algae occurs by sexual, asexual, and vegetative methods. A vegetative method includes fragmentation, fission, akinete, tuber, and hormogonia. Asexual reproduction involves the division of protoplast and this protoplast grows into new plants. It occurs by forming spores like zoospores, syn-zoospores, aplnospores, autospores, auxospores, etc. Sexual reproduction is the fusion of male and female gamete. It is of isogamous, anisogamous, and oogamous (Bhuju et al., 2065).

Algae are unicellular microscopic organisms i.e. microalgae and can extend to greater size i.e. macro algae(Munir et al., 2013). Microalgae consists of diatoms, some green algae, dinoflagel lates, euglenids, and some red algae and contain single flagella. They are free-floating and their body shape appears to be filaments. Some microalgae like volvox live in a colony. Macro algae consist of brown algae, green algae, and red algae. It contains holdfast which helps to keep the plant in one place (Fall et al., 2010). Blades are the main sites of photosynthesis in algae (Robers et al., 2007). Algae are found in both land and water environments. Epiphloephytes, epiphyllophytes, and lithophytes, are the terrestrial form of algae whereas phytoplanktons, benthic/ Cryptophytic, epiphytic, epizoic, endozoic, and periphytic are the different aquatic algae. Cryophytes are those algae which can sustain in low temperature i.e. on snow E.g. *Haematococcus,Scotiella* etc whereas thermophytes can tolerate high temperature i.e. on hot spring water E.g. *Oscillatoria brevis*(Blue green algae), *Haplosiphon.*

Algae plays a major role in the purification of the environment, to meet the current demand for biofuels and reduce the pressure of petroleum and diesel fuels, which are going to be exhausted soon. More over when food is scarce, algae can provide the nutrient diets to human beings and animals Algae reduces the concentration of carbon dioxide in the atmosphere and gives oxygen which is one of the most essential requirements for the existence of life. Algae act as biofertilizers and improve the soil structure, porosity, and texture. Water blooms produced by the Blue Green Algae and Green algae lead to the death of aquatic organisms (Hasan and Chakrabarti, 2009). Red rust of tea and coffee is caused due to Cephaleuros *virescence* and *Cephaleuros arabica.*

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1.1 Types Of Algae

Although alga looks simple in forms and structures they have diverse classifications. According to 11 classes are present based on pigment and reserve food materials of algae, which are as follows (Fritsch, 1935)

Table 1: Classification of algae (Elnabris, 2000)

Name	Occurrence	Orders	Structure	Pigments	Reserve food	Pyrenoids	Cell wall	Flagella	Reproduction	Examples
Eugleuineae	Fresh water	-	Unicellular	Chl-a,Chl-c,β carotene	Polysaccharide and paramylon	Similar structures	Proteinaceous	One or two	Cell division, Sexual rare(isogamous)	*Euglena*
Chloromonadophyceae	Fresh water	1	Motile unicells	Chl-a, xanthophylls	Fats or oils	Absents	Absent	Biflagellate equal	Cell division, Sexual reproduction absent	*Gonyostomum*
Bacillariophyceae	Cosmopolitan distribution, even in soil, terrestrial	2	Unicellular or colonial	Chl-a,Chl-c,β carotene Fucoxanthin, Diatoxanthin, didinoxanthin	Fats, Volutin	Present	Silicaceous(outer) and pectic(inner)	Single flagella	Cell division and auxospore	*Pinnularia, Cymbella, Navicula*
Cryptophyceae	Both freshwater and marine	2	Unicellular with anterior groove or pocket	Chl-a,Chl-c, Diatoxanthin	Starch or oil	Pyrenoid like structures is present.	Absent	Biflagellate, equal or unequal	Binary fission, sexual rare(isogamous)	*Chroomonas, Cryptomonas,*
Chrysophyceae	Mostly freshwater, few marine	3	Unicelled motile to filamentous branched	Chl-a,Chl-c,β carotene, Phycochrysin	Leucosin, fats,Chrysolaminarin	Absent	Silicaceous or calcified, cellulose absent	2 equal or unequal flagella	Vegetative,asexual, sexual rare(isogamous)	*Prymnesium, Dinobryon, Chrysophaera*
Xanthophyceae	Mostly freshwater, few marine	4	Unicelled motile to filamentous	Chl-a, Chl-e and β carotene, xanthophyll, neoxanthin, and violaxanthin	Oil	Absent	Rich in Pectin	2 unequal flagella (heterokont)	Vegetative, asexual, sexual, (mainly isogamous, anisogamous rare,oogamy in *Vaucheria*)	*Chlorogloea, Tribonema, Chlorogloea, Botrydium*
Myxophyceae	Fresh water	5	Unicellular, prokaryotic	Chl-a, xanthophylls phycoerythrin, and blue phycocyanin, carotenes	Cyanophycean starch		Peptidoglycan	Absent	Asexual reproduction by fragmentation, fission, akinetes, hormogonia	*Oscillatoria, Nostoc*
Dinophyceae	Mostly marine	6	Unicellular, branched filamentous	Chl-a,Chl-c,β carotene, xanthophyll peridinin, neoperidinin etc	Starch or fats		Cellulose	Biflagellate, equal	Sexual rare(isogamous)	*Ceratium, Noctiluca, peridinum*
Rhodophyceae	Mostly marine, rarely fresh water	7	Unicellular to complex, Parenchymatous to non parenchymatous thallus seaweeds	Chl-a,Chl-d, phycoerythrin and blue phycocyanin, carotenes.	Floridean starch		Outer wall polysaccharides, inner wall cellulose	Absent	Advance oogamous	*Thorea, Gelidum, Champia, Ceramium, Corallina*
Chlorophyceae	Aquatic, mostly freshwater, few are terrestrial	9	Unicellular, multicellular to hetetrotrichus, filamentous	Chl-a,chl-b, and αβγcarotenes, lycopene, xanthophyll	Starch	Present	Cellulosic	Motile cells, equal flagella	Vegetative, asexual, sexual(isogamous, anisogamous to advanced oogamous)	*Volvox, pediastrum, ulothrix, cladophora, cephaleuros, Chara, Oedogonium*
Phaeophyceae	Marine	9	Multicellular to giant sea weeds (kelps)	Chl-a,Chl-c,β carotene, xanthophylls	Mannitol, laminarin and oils		Polysaccharides alginates & fucose-containing sulfated polysaccharides	Motile gametes 2 laterally attached flagella heterokont	Asexual(fragemtation or zoospores) Sexually (isogamous,oogamous or anisogamous)	*Ectocarpus, Tilopteris,Cutieria, Sphaecelaria, Sargassum, Dicotyota, Sporochnus*

1.2 Diversity of Algae in Nepal

Algae can suit from adverse climate to favourable environment. In all districts, few to many varities are found. Following are the districts where research activities have been performed-

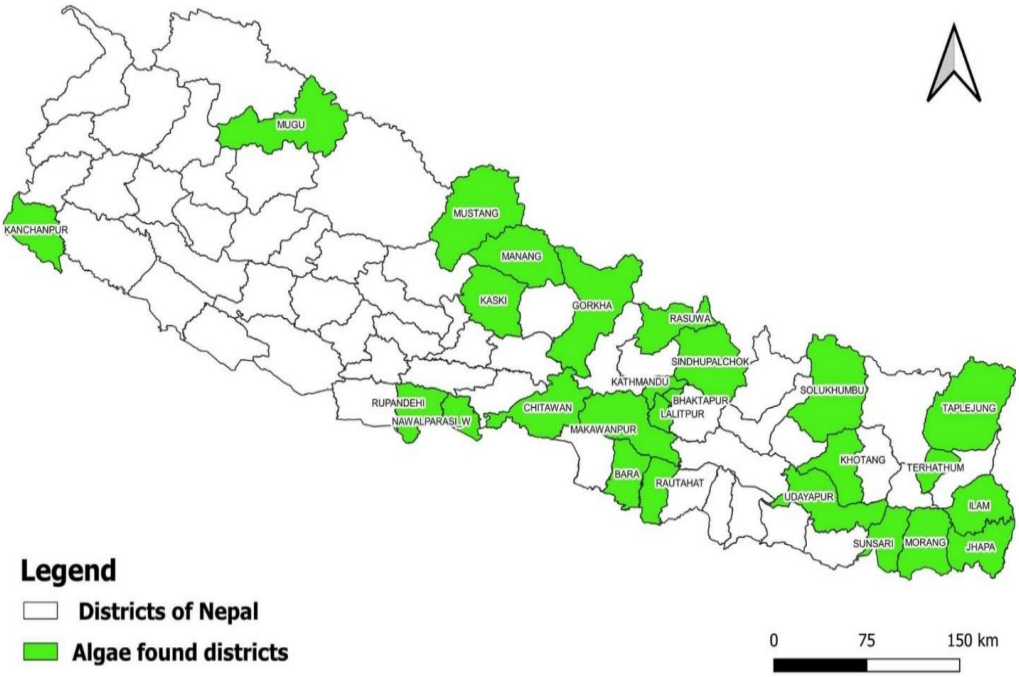

Figure 1: Distribution of Algae in Nepal

Due to the difficult land structures, climate and technology most of the research activities are performed in city areas which results for the hinderance of algae found in the remote areas. Some efforts have been made by different researchers to find different types of algae in different geographical regions are mentioned below-

Table 2: Algae diversity along with districts of Nepal

S.N	Location	Name	References
1	Bara	*Gloeocapsa decorticans, Gloeothece rupestris, Aulosira fertilissima, Aulosira fertilissima, Nostoc commune*	(Prasad, 1996)
2	Bhaktapur	*Schizothrix purpurascens, Nostoc sphericum, Scytonema fertilia, Hapalosiphon intricatus, Stigonema hormoides, Westiellopsis species, Nostoc linckia, Scytonema bewsii, Calothrix fusca, Aulosira implexa, Phormidium autumnale, Cylindrospermum majus*	(Shrestha and Manandhar, 1983; Watanabe and Komarek, 1988)
3	Chitwan	*Aphanocapsa elachista, Aphanocapsa rivularis, Arthrospira spirulinoides, Lyngbya lattissima, Anabaena sphaerica Aulosira fritschii, Aulosira prolifica, Aulosira fertilissima, Microcoleus chthonoplastes, Synechocystis aquatilis, Oscillatoria sancta, Oscillatoria granulate, Oscillatoria princeps, Synechocystis pevalekii, Oscillatoria irrigua, Chroococcus minutus*	(Das and Verma, 1996)
4	Gorkha	*Dactylococcopsis raphidioides, Merismopedia tenuissima, Oscillatoria granulata*	(Hirano, 1955)
5	Illam	*Microcoleus sociatus, Phormidium subfuscum, Hapalosiphon fontinalis, Lyngbya hieronymusii*	(Rai and Misra, 2010)
6	Jhapa	*Chroococcus schizodermaticus, Gloeocapsa nigrescens, Tolypothrix distorta, Rivularia minutula, Eucapsis himalayensis*	(Rai and Misra, 2010)
7	Kanchanpur	*Aphanocapsa roeseana, Aphanothece microscopica, Microcystis marginata, Lyngbya contorta, Oscillatoria Formosa, Phormidium incrustatum, Phormidium usterii* *Aulosira fertilissima, Gloeotrichia natans, Lyngbya hieronymusii, Lyngbya allorgei, Anabaena iyengarii, Nostoc linckia, Nostoc linckia, Lyngbya hieronymusii, Lyngbya allorgei, Anabaena iyengarii.*	(Habib, 1997)
8	Kaski	*Anabaena circinalis, Microcystis aeruginosa, Microcystis flosaqua, Spirulina gigantea*	(Nakanishi, 1986; Hickel, 1997)
9	Kathmandu	*Aphanocapsa anodontae, Aphanothece pallida, Gloeocapsa aeruginosa, Gloeocapsa atrata, Gloeocapsa dermochroa, Gloeocapsa sanguinea, Gloeothece fusco-lutea, Holopedium irregulare* *Nephrococcus species, Cyanosarcina species, Lyngbya lagerheimii, Lyngbya maior, Microcoleus vaginatus, Oscillatoria acuminate, Oscillatoria granulate, Oscillatoria proteus, Oscillatoria subproboscidea, Phormidium ambiguum Phormidium fragile, Schizothrix friesii Schizothrix heufleri, Schizothrix pulvinate Anabaena fertilissima, Anabaena globose Pseudanabaena catenata, Scytonema arcangelii, Scytonema contorta, Scytonema myochrous, Scytonema schmidtii, Scytonema stuposum Tolypothrix arenophila, Tolypothrix phyllophila, Calothrix fusca, Calothrix scytonemicola, Oscillatoria foreaui,Oscillatoria okeni, Nostoc linckia, Scytonema bewsii, Oscillatoria granulate Microcystis flosaquae, Phormidium anomala, Calothrix fusca, Rivularia minutula, Lyngbya allorgei, Phormidium uncinatum, Oscillatoria anguina, Nodularia harveyana, Anabaena doliolum, Oscillatoria jasorvensis, Phormidium retzii, Cylindrospermum minutissimum, Cylindrospermum stagnale , Nostoc calcicola, Nostoc ellipsosporum, Calothrix parietina, Merismopedia glauca, Chroococcus turgidus, Gomphosphaeria aponina, Microcystis robusta, Aphanocapsa grevillea,*	(Baral et al.,1988; Hirano, 1963; Watanabe and Komarek, 1988; Watanabe, 1995)

		Oscillatoria irrigua, Merismopedia punctate, Oscillatoria proboscidea, Lyngbya aerugineocoerulea, Nostoc spongiaeforme, Oscillatoria limosa, Chroococcus limneticus.	
10	Khotang	*Oscillatoria amoena, Oscillatoria curviceps, Phormidium anomala, Oscillatoria amoena,Oscillatoria curviceps, Spirulina major.*	(Rai and Misra, 2010)
11	Lalitpur	*Aphanocapsa pulchra, Chroococcus minor Gloeocapsa muralis, Chamaesiphon confervicola, Chamaesiphon minutus, Blennothrix ganeshii, Lyngbya bipunctata, Oscillatoria acutissima, Phormidium corium, Nostoc muscorum, Nostoc paludosum, Scytonema bewsii, Scytonema ocellatum, Homoeothrix janthina, Scytonema bewsii, Aulosira implexa, Oscillatoria princeps, Cylindrospermum stagnale, Nostoc calcicola, Nostoc ellipsosporum, Lyngbya birgei,Nostochopsis lobatus, Oscillatoria amoena, Oscillatoria subbrevis, Oscillatoria chlorine,Calothrix parietina, Microcystis stagnalis, Anabaena variabilis.*	(Joshi, 1977; Joshi, 1979; Prasad and Prasad, 2001; Rai and Misra, 2010)
12	Lamjung	*Lyngbya confervoides, Oscillatoria deflexa, Oscillatoria laete-virens, Phormidium jadinianum, Phormidium stagnina, Anabaena flosaquae, Microcoleus lacustris*	(Panta and Gupta, 1999)
13	Makawanpur	*Dactylococcopsis acicularis, Oscillatoria annae, Merismopedia elegans, Spirulina meneghiniana*	(Sahay et al., 1993)
14	Manang	*Aphanocapsa delicatissima, Oscillatoria amphibian, Oscillatoria terebriformis, Phormidium papyraceum, Phormidium purpurascens, Arthronema africanum, Phormidium autumnale, Calothrix parietina, Merismopedia glauca, Chroococcus turgidus, Gomphosphaeria aponina.*	(Hirano, 1955; Komarek and Lukavsky, 1988)
15	Morang	*Arthrospira khannae, Lyngbya majuscule, Calothrix castellii, Gloeotrichia intermedia, Fischerella epiphytica, Oscillatoria sancta Oscillatoria anguina, Lyngbya birgei, Nostochopsis lobatus, Microcystis robusta, Aphanocapsa grevillea, Spirulina subsalsa, Spirulina princeps.*	(Rai and Misra, 2010)
16	Mugu	*Aphanothece stagnina, Leptolyngbya perelegans, Leptolyngbya rivulariarum, Anabaena lapponica, Anabaena oscillarioides, Pseudanabaena mucicola, Microchaete tenera, Calothrix gloeocola, Phormidium tenue, Nodularia harveyana, Cylindrospermum minutissimum, Chroococcus minutus, Rivularia hansgirgi*	(Watanabe, 1995)
17	Mustang	*Synechococcus aeruginosus, Phormidium laminnatum, Gomphosphaeria aponina, Synechococcus aeruginosus, Phormidium laminnatum, Oscillatoria irrigua, Merismopedia punctate, Oscillatoria proboscidea, Microcystis stagnalis, Chroococcus minutus.*	(Hirano, 1955; Upadhyaya, 1979)
18	Nawalparasi	*Oscillatoria borneti, Anabaena augstumalis, Anabaena unispora, Calothrix atricha, Calothrix castellii, Spirulina gigantean, Oscillatoria agardhii, Anabaena variabilis*	(Das and Verma, 1996)
19	Parsa	*Gloeocapsa rupestris, Arthrospira platensis, Phormidium lucidum, Anabaena azollae, Anabaenopsis raciborskii, Raphidiopsis curvata, Gloeocapsa decorticans, Gloeothece rupestris*	(Prasad, 1996)
20	Rasuwa	*Aphanocapsa elachista, Chamaesiphon incrustans, Hydrocoleus homoeotrichum, Lyngbya epiphytica, Lyngbya sordida, Oscillatoria brevis, Oscillatoria pseudominima, Phormidium valderiae, Schizothrix lacustris, Anabaena papillosa, Scytonema mirabile, Aphanocapsa grevillea, Oscillatoria splendida, Lyngbya aerugineocoerulea, Stigonema ocellatum, Stigonema mamillosum, Oscillatoria animalis*	(Hirano, 1969; Yoshimura et al., 1997; 2006)
21	Rautahat	*Chroococcus limneticus, Eucapsis minuta, Merismopedia minima, Synechococcus Elongates, Arthrospira massartii, Oscillatoria articulate, Hapalosiphon welwitschii, Gloeocapsa decorticans, Gloeothece rupestris, Merismopedia punctate, Microcoleus subtorrulosus, Nostoc microscopicum, Cylindrospermum majus, Anabaena iyengarii, Chroococcus tenax, Chroococcus minutus*	(Sahay et al., 1993)
22	Sankhuwasabha	*Scytonema burmanicum, Stigonema ocellatum, Chlorogloea simplex*	(Rai and Misra, 2010)
23	Sarlahi	*Oscillatoria mougeotii, Spirulina major, Spirulina subsalsa*	(Sahay et al., 1993
24	Sindupalchowk	*Oscillatoria granulate, Oscillatoria jasorvensis, Oscillatoria subbrevis, Trochiscia species, Oscillatoria limosa*	(Yoshimura et al., 1997; 2006)
25	Solukhumbu	*Aphanocapsa muscicola, Phanothece castagnei, Aphanothece nidulans, Chroococcus turicensis, Chroococcus varius, Dactylococcopsis epiphyticum, Gloeocapsopsis ferruginea, Lemmermanniella, Mantellum himalayense. Chlorogloea microcystoides, Chamaesiphon jaoi, Chamaesiphon minimus, Chamaesiphon palssahtiae, Clastidium nepalense, Clastidium sicyoideum, Xenococcus luteo-violaceus, Schizothrix flammea, Schizothrix radius-solis, Anabaena laxa, Cylindrospermum breve, Cylindrospermum indicum, Coleodesmium sagarmathae, Fortiea species, Microchaete aequalis, Entophysalis rubra Want, Chroococcus tenax, Eucapsis himalayensis, Chroococcus limneticus, Stigonema mamillosum, Chlorogloea simplex, Woronichinia kuselae, Chroococcus minutus*	(Komarek and Watanabe, 1998; Watanabe and Komarek, 1994; Komarek and Watanabe, 1990; Subbha and Suxena, 1979)
26	Sunsari	*Aphanocapsa biformis, Chroococcus hansgirgi, Microcystis incerta, Myxosarcina spectabilis, Arthrospira gomontiana, Oscillatoria acuta, Oscillatoria chalybea, Oscillatoria hamelii, Oscillatoria ornate, Oscillatoria vizagapatensis, Phormidium molle, Phormidium rubroterricola, Spirulina subtilissima, Symploca flotowiana, Anabaena naviculoides, Cylindrospermum stagnale, Scytonema javanicum, Gloeotrichia raciborskii,Rivularia aquatic, Microcoleus chthonoplastesSynechocystis aquatilis, Oscillatoria sancta, Spirulina gigantean, Oscillatoria chlorine, Spirulina meneghiniana, Oscillatoria splendida, Anabaena iyengarii, Spirulina subsalsa, Oscillatoria obscura, Woronichinia kuselae, Microcoleus lacustri, Spirulina princeps, Rivularia hansgirgi, Gloeotrichia intermedia, Anabaena iyengarii*	(Jha and Kargupta, 2001)
27	Taplegunj	*Lyngbya limnetica*	(Hirano, 1963)
28	Tehrathum	*Phormidium favosum, Phormidium inundatum, Phormidium laminosum*	(Hirano, 1963
29	Udayapur	*Aphanothece naegelii, Coelosphaerium dubium, Gloeotrichia echinulate, Anabaena volzii, Anabaena iyengarii*	(Rai and Misra, 2010)
30	Birjung	*Oscillatoria proboscidea, Anabaenopsis raciborskii*	(Prasad, 1996)
31	Rupendehi	*Nostoc spongiaeforme*	(Gyawali and Prasad, 1999)

2. APPLICATION OF ALGAE

2.1 Algae as bio- fertilizers

Bio fertilizers are the substances that comprises of microorganism, which when applied colonizes the rhizosphere and makes availability of the nutrients which ultimatey helps in the growth and development of plant. It accelerates the function of microorganisms. Bio fertilizers are environment friendly and are capable of enhancing soil, crop growth and yield(Chatterjee et al., 2017). They are cheaper than other commercial insecticides and pesticides. Moreover biofertilizers do not pollute the environment like insecticides and pesticides. They are much cheaper and can be used by every farmer with general knowledge. They promote growth of plant by suppressing growth of other pathogens and diseases and are renewable sources(Scheler, 2011).

Due to the higher use of land, soil texture and fertility is decreasing day by day as a result yield is highly reduced. In order to maintain the soil quality and ultimately higher yield, algae plays a major role and acts as biofertlizers(Mahapatra et al., 2018).Algae like BGA have better capacity to fix atmospheric nitrogen under flooded condition than in dry land. An alga plays different roles and act as biofertilizers. Algae produces the adhesive substances which increases the porosity of the soil(Sahu, 2012).It excretes organic acid rich in phosphates. It tends to decreases the ph of the soil. After the death of algae biomass is added into the soil(Purwani et al., 2021). Weed growth is suppressed. the jelly structure in algae helps to hold the water, which can be used by the plants for long time (Roger and Reynaud, 1982).16. It liberates the growth hormones, vitamins, amino acid necessary for the plant growth(Rodríguez et al., 2006). As stable soil aggregates are responsible for the soil fertility, algae are responsible for the improvement of soil aggregates(Burns and Davies, 1986). Soil aggregates which are bounded by the BGA are found to have high water holding capacity(BAILEY et al., 1973).Carbon acts as the major sources for the soil bacteria , that helps in th colonization of rhizosphere through exopolysaccharides and exudates of Algae(Kapustka and DuBois, 1987).

Brown macroalgae like *Saccharina latissima, Laminaria digitata, Stoechospermum marginatum , Ascophyllum nodosum, Fucus vesiculosus, Ecklonia maxima*, contributes to increase nitrogen, potassium, phosphorous and carbohydrates in the soil(Eris et al., 1995; Ramya et al., 2015). Carbohydrates improves soil structure and soil aeration have good water holding capacity(Norrie & Keathley, 2006; Sharma et al., 2014). It contributes for naturally occuring harmones and growth regulators. It protects the plant from salt, freezing and drought conditions and enhances plant for photosynthethetic activity and controls fungi, virus and bacteria (Craigie, 2011; Khan et al., 2011). Red Macroalgae like *Phymatolithon calcareum* (Maerla), *Lithothamnion corallioides* (Maerla) helps in the fulfilment of trace elements to soil(McHugh, 2003; Smit, 2009). Blue green algae like *Nostoc, Anabaena, Aulosira, Tolypothrix, Nodularia, Cylindrospermum, Scytonema, Aphanothece, Calothrix, Anabaenopsis, Mastigocladus, Fischerella, Stigonema, Haplosiphon, Chlorogloeopsis* fixes 18- 45 kg N/ ha in submerged rice field and produces growth promoting substances(Chatterjee et al., 2017; DE, 1939). *Anabaena Azolla* association fixes 40-80 kg of Nitrogen/ ha and can be used as green manure because of large bio mass(Moore, 1969; Vaishampayan et al., 2001).

2.2 Algae for medicines

a. Goitre treatment

Lack of iodine in body causes swelling of the muscles near the neck region which is referred as Goitre in medical terms. Algae have high amount of iodine and hence they are used to treat Goitre. (Stein and Borden 1984).

b. Obstetrical Uses

Dried stripes of brown green algae which are popularly known as 'laminaria tent' which fuctions as cervical dilators during obstetrical and gynecological practices (Newton 1972; Hale & Pion 1972; Feochari 1979).It is used for birth countrol (Manabe et al., 1982).

c. Vermifuge activity

Vermifuge is a medicine that is used to kill parasites without causing damages to the host. Red algae secretes kainic acid which helps to block neuromuscular in worm (Michanek 1979). Domic acid produced by Digenea simplex and Chondria armata behave as anthelmintic agent (Higa and Kuniyoshi 2000). Secretions from macro algae such as kainoids, terpenoids are insecticidal (Maeda et al., 1984).

d. Thalassotherapy

For the treatment of osteoporosis and rheumatism, the paste of macroalgae is used. In this method, macroalgae are crushed down into small pieces and paste is made, this paste is colled and applied over the persons body followed by warming with the help of infrared radiation (Barsanti and Gualtieri, 2006).

e. Biocosmetics

Microalgae such as Spirulina (Arthrospira) and Chlorella are used for the production of cosmetic items. Such obtained cosmetic items would work for face, skin, hands, hair and acts as refreshing items, emollient creams, anti-aging cream, and anti-irritant etc(Stolz and Obermayer 2005).

f. Antioxidant activity

Due to the excessive emotional and physical stress in daily life, it leads for the production of active free radicles. These free radicles affects the metabolism process and leads for the destruction of DNA (Barry and Aruoma, 1991), and protein synthesisis.(Martin and Dean, 1991). Because of this it enhances aging process and give rise to different diseases like cancer, cardiovascular, chronic inflamation and ageing processes(Barry and Gutteridge, 1989).Algae contains antioxidants like β-carotene, astaxanthin and canthaxanthin (Borowitzka, 1988a; Lee and Zhang, 1999), polyphenols, vitamins and phycobiliproteins(Plaza et al., 2008), which helps to reduce the carcinogenesis by scavenging free radicals and active oxygen. Beta carotene present in the algae helps to prevent from leukoplakia (Sithranga Boopathy and Kathiresan, 2010).

g. Antibiotic activity

Algae maily in macroalgae have large number of chemical compounds that works as antibiotic activities (Stein and Borden, 1984; Lincoln, et al., 1991; Smit, 2004; Chanda, et al., 2010). Some green algae and microalgae produces acrylic acid from *Phaeocystis pouchettii* (Fenicol, 1975; Hashimoto, 1979) and Chlorellin from *Chlorella* also behaves as antibiotics. Methanol extracts from *Cladophora* helps to control *Staphylococcus aureus* and *Bacillus mycoides* activity (Demina and Mal'dov, 1981)

h. Anticardiovascular disease activity

High cholesteol levels leads to the blood pressure and ultimately causes cardiovascular diseases. The polysaccharides present in the algae like alginates carrageenans (Kiriyama, et al., 1968), funorans, fucoidans (Lamela, et al., 1989), laminarans, porphyrans, ulvans produces hypocholesterolemic and hypolipidemic activity and reduces cholesteol level in the body(Panlasigui, et al., 2003). Systolic pressure in the body is reduced by algal polysaccharides and this activity leads to reduce the occurrence of cardiovascular diseases (Renn, et al., 1994).

i Anticoagulant and antithrombic activity

Anticoagulant and antithrombic are the terms that prevents the blood from clotting. Algae that contain sulfated polysachharides, fucoidins acts as anticoagulants and antithrombic. Fucoid helps in the synthesis of blood by regulating heparin cofactor II or antithrombin III (Church, et al., 1989; Colliec, et al., 1991; Matou, et al., 2002). Major anticoagulant substances like sulfated fucans are produced from *Ascophyllum nodosum* and *Fucus vesiculosus* (Smit, 2004).

j. Anticancer and antitumor activity

the debromoaphysiatoxin obtained from the BGA showed against Lymphotic mouse leukemia (Mynderse, et al., 1977). Kahalalide F taken from *Bryopsis*(Hamann and Scheuer, 1993; Hamann, et al., 1996)., and extracts from Chondria atropurpurea(Palermo, et al., 1992), Bifurcaria bifurcata(Valls, et al., 1995), *Sargassum sp., Laminaria sp*.(Yamamoto, et al., 1974, 1981) have anticancer and antitumer property which have ability to control lung colon, prostrate, nasopharyngeal cancer(Scheuer, et al., 2000).

k. Antiviral activity

Dextran sulfate, heparin, sulfated galactan, sulfated xylomannan, pentosan polysulfate from the algae found effective in controlling HIV agents (Witvrouw and De Clercq, 1997). Moreover such algae produces the enzymes that controls respiratory syncytial virus (RSV), human cytomegalovirus (HCMV), herpes simplex virus (HSV) and influenza virus (Damonte et al. 1994),*Schizymenia pacifica, ,Gracilaria corticata, Aghardhiella tenera, Nothogenia fastigata* are the important enzymes secreated by algae that mainly works as antiviral activity.

l.. Anti-inflammatory activity

living tissues suffers from inflamation and it leads for the deah of cell and occurance of several diseases(Jaswir and Monsur, 2011).Macroalgae grows naturally in aquatic environment and have capacity to tolerate several stress condition and can tigger immonological responses in man(Pompani, 2001; Ehrlich 2010).Sulfated polysaccharides mainly alkaloids (Caulerpin I, II, III) obtained from red and green algae, fucoidins obtained brown algae,and fucoxanthin and astaxanthin(carotenoids), Vidalols A and B and Phaeophytin A are anti-inflammatory compounds(Bhakuni and Rawat, 2005; Jaswir and Monsur, 2011).

2.3 Algae as food

Algae are the primary producers of ecosystem which contains chlorophyll and can prepare its food by itself. Algae are considered very important source of food to quench thirst and hungriness since ancient time. During world wars, people eat *Chondrus crispus* to get energy. In Germany breads made from ground algae was prepared. *Pyropia columbina* have greater thirst-quenching tendency(Schwimmer and Schwimmer, 1955). The food obtained from the algae could be beneficial as well as harmful to the human beings and animals. The food which contain elements like cadmium or fucotoxins are harmful, which aims to protect algae from herbivore and pathogens.(Pooja, 2014) Algae are rich in protein, vitamins, minerals, amino acids, dietary fibres, lipids, polysaccharides and fatty acids. As algae do not have any circulation system, it have higher energy as compared to the higher plants. The different types of nutrients found in algae which are necessary for the animals and humans are mentioned below-

a. Polysachharides

Polysachharides are the chemical substance whose molecules contain bounded carbon atoms. *Odontella, Aphanizomenon, Haematococcus, Arthrospira, (Spirulina), Chlorella, Porphyridium, Scenedesmus, Dunaliella* are the algae containing polysaccharides. Green alga contains sulphuric acid polysaccharide and sulfated galactans, brown algae (Pheophyceae) contains laminarin, fucoidan and. alginic acid and red algae (Rhodophyceae) contains floridean, carrageenan and porphyran. Among the different types of algae Ulva species cointain high quantity of polysaccharides(Pal et al., 2014). Watersoluble pollysachharides shows hypoglycemic and hypocholesterolemic effects and water insoluble polysachharides shows laxative effects (Burtin, 2003). Polysachharides helps to maintain sugar level by removing or adding glucose in the human body.

b) Dietary fibres

these are the substance which are indigestible obtained from the plants. Algae produces alginic acid, agars, furonan, laminarin and porphyran, cellulose, mannans and xylan as dietary fibres.These fibres helps to regulate the metabolism process in the body makes body healthy. Dietary fiber content found in some algae is as shown in following tables (Mabeau and Fleurence, 1993).

Table 3: Dietary content of algae

Algae	Dietary fibre %
Phaeophyceae	
Himanthalia elongate	32.70
Sargassum fusiforme syn. Hizikia fusiforme	49.20
Undaria pinnatifida	35.30
Laminaria digitata Undaria	38
Chlorophyceae	
Ulva lactuc	38
Rhodophyceae	
Pyropia tenera	34.80

c) Protein and amino acids

Algae contains different types of proteins and amino acids that differ from each others. Red and green algae have comparatively high amount of proteins as compared to brown algae. Ulva species contains 15-20 % of proteins. Amino acids like alanine, aminobutyric acid, citrulline, hydroxyl proline, ornithine and taurine as structural element, glutamic acid, and aspartic acid are present in all algae(Wells et al., 2017). Algae can also produce amino acids like leucine, methionine, tryptophan, lysine, threonine, and valine which human body cannot synthesize(Mabeau and Fleurence, 1993).Protein and amino acids helps for the formation of new cells in the body.

d) Lipids and fatty acids

Algae contain the lipids and fats which are required for the body. Alpha linolenic acid in green algae eicosapentanoic acid in brown algae and docosahexanoic acid in red algae are present (Kolanjinathan et al., 2014). All the fats and lipids while consuming by human helps to regulate human physiology and metabolism. *Porphyridium cruentum, Nitzschia laevis, Phaeodactylum tricornutum* cointains eicosapentaenoic acid whereas docosahexanoic acid is found in *Crypthecodinium cohnii, Schizochytrium mangrovei*(Martins et al., 2013). Moreover green algae contain cholesterol, β- sitosterol and methylene cholesterol and Desmosterol, cholesterol, chalinasterol, sitosterol, and fucosterol in red algae that helps to regulate blood in the body.

e) Minerals

For the proper functioning of the body, human body requires different types of minerals such as iron, iodine, phospsorous, potassium, calcium etc. This type of needs can be fulfilled while consuming macroalgae(Kolanjinathan et al., 2014). Genus *Porphyra* contains high iron, *Pseudofallacia tenera* gives high manganese, *and Seaweeds, Laminaria and Saccharina* species are are nutritional sources for iodine.

f) Vitamins

Vitamins are responsible fot the growth and development of the body. Deficiency of vitamins leads for the different type of diseases realated to bones, eye, skin, etc. Algae such as *Palmaria palmata* and *Porphyra tenera* provide vitamins A, B1, B2 and B12. *Gracilaria chilensis* and *Codium fragile* provides pro-vitamin A (β-carotene)**.***Chlorella stigmatophora, Dunaliella tertiolecta, Isochrysis galbana and Tetraselmis suecica* posses vitamins A,B,E whereas *Ulva* and *Pyropia* sp. contains relatively less quantity of vitamin B12(Wells et al., 2017). Brown algae contain vitamin E comparatively greater than green and red seaweeds.

2.4 Algae for biofuels

Algae are a unicellular organism that grows in moist environments. They are also considered as fastest growing organisms.Like other higher plants the process of food production of algae is similar, they utilize water,sunglight, CO2 and others nutrients to librate huge amount of energy and oxygen to the atmoshphere. Algae can produce the renewable raw materials required for the biofuels. The oil extracted from the algae can be used directly as a biofuels including renewable diesel, jet fuels etc. The renewabe disesel and jet fuels can be used directly in the engine that replaces petroleum, without causing any damages to the engines. If fuels can be obtained /produced in large quantities in near future, algae fuel can replace petroleum completely. Pyrolysis oil can be obtained from the algae that help in heat and power consumption.

Algae as biofuel have several advantages. Algae are the renewable sources of energy that can be grown everywhere using saltwater, brackish water and it does not need any special care for its growth. If we have proper amounted of sunlight available we dont have any difficult in growing algae. As it is a small plant having less metabolism activities, as a result less amount of energy is lost for its activities and huge amount of it is stored. This stored form of energy can be used for biofuels. Research shows that biofuels obtained from the algae are more than that of terrestrial plant. As carbohydrate is needed in large amount for human and and animals, algae can utilize large amount of atmoshpheric carbon and convert into organic carbon. If we use algal biofuel than out net consumption of biofuel is nearly zero because algae are highly renewable sources of energy and can utilize it without causing any stress to environment. Process for the making algae as biofuels is similar to the purification of current biofuels. That means, we can use algal biofuel to meet the situation of other biofuels which are non-renewable in nature. Algae can be double in population within 24 hrs only so there wont be any scarcity of raw materials as biofuels.Moreover algae can be used for the production of numerous products like fertilizers, soaps etc,which requires the hydrocarbons similar to the petroleum products. Everythings have both positive and negeative sides. Algae too have constrains also for making algae as biofuels. Algae require large quantity of water for its proper growth and development. If less amount of water is available then, the small water temperature rises fast and and which hinders the growth of algae. Algae require fetilizers like phosphorus for its proper growth. If we want to grow algae in artificial environment starting cost of production would be very large amount. We have to construct a place which holds water in high quality which is not possible with a small

investment. Algae products can be harvested daily, but you cannot utilize this product a biofuels immediately; we should follow some steps like storaging in desire conditions, crushing, purifications etc for a biofuels. Although algae grows in different climates but it cannot grow in extreme climates. Cultivation of single crops for a long time causes the emergence of pest and insects. As many types of algae are found, while processing the biofuels, it creates variabity in quality.

2.5 Bioremediation Of Organic Pollution

Bioremedation is a process by which substances which degrade the natural environment are break down and reduces their effects by microorganism. Algae being easily available help to fix the harmful wastage from industry, oil effulents, organic and inorganic pollutants. Different types of pollutants are described along with the potential algal species involved in their degradation.

Table 4: Pollutants absorbed by algae

Pollutant	*Algae*	References
Cu^{2+}	*Anabaena cylindrica Asterionella formosa Chlorella fusca Chlorella miniata Chlorella spp*	(Çetinkaya Dönmez et al., 1999; Tien et al., 2005)
Fe^{3+}	*Chlorella vulgaris Microcystis sp*	(Romera et al., 2006; S. Singh et al., 1998)
Hg^{2+}	*Calothrix parietina TISTR 8093 Chlamydomonas reinhardtii Cyclotella cryptica Pseudochlorococcum typicum Spirogyra hyalina*	(Bayramoğlu et al., 2006; Schmitt et al., 2001)
Ni^{2+}	*Arthrospira (Spirulina) platensis Chlamydomonas reinhardtii Chlorella miniata Chlorella spp. Chlorella vulgaris Chlorella vulgaris Chlorella vulgaris*	(Ferreira et al., 2011)
Pb^{2+}	*Arthrospira (Spirulina) platensis Chlamydomonas reinhardtii Chlorella vulgaris BCC 15 Oscillatoria laete-virens Pseudochlorococcum typicum Spirogyra insignis Spirulina (Arthrospira) platensis*	(Romera et al., 2007)
$Zn^{2=}$	*Aulosira fertilissima Desmodesmus pleiomorphus Isochrysis galbana Planothidium lanceolatum Spirulina spp. Stigeoclonium tenue Scenedesmus subspicatus*	(Singh et al., 2007)
Cd^{2+}	*Chaetoceros calcitrans Chlamydomonas reinhardtii Chlamydomonas reinhardtii Desmodesmus pleiomorphus (ACOI 561) Isochrysis galbana*	(Monteiro et al., 2010; Tüzün et al., 2005)
Cr^{5+}	*Spirulina sp. Chlamydomonas reinhardtii Chlamydomonas reinhardtii Spirulina Spirulina spp. Ulothrix tenuissima*	(Ming-Ju Chen, Kreuter, 1996)
$Cr_2o_7^{-2}$	*Chlorella spp. Spirulina sp.(HD-104)*	(Doshi et al., 2008)
Cd	*Cadmium(Cd)* *Spirogyra sps. And Oscillatoria sps.*	(Brahmbhatt et al, 2012)
Co, Pb,Hg	*Spirogyra hyaline*	(Shanab et al., 2012)
No_3	*Chlorella vulgaris, Chlorella minutissima and Scenedesmus quadricauda*	(Kshirsagar, 2013)
Textile waste	*Chlorella vulgaris*	(Kassas and Mohamed, 2014)

3. Future Prospectus of Algae

Population of the world is increasing day by day. Most of the cultivable lands are occupied by the buildings, in such conditions there can be scarcity of land for growing food. At present also we can see no cultivable land left in city areas also. Due to the increasing population scenario in near future all the areas of the world would be covered by either building or water. Due to this world could be suffered from scarcity of food. As algae can be grown in water resources, algae which contain nutritional diet for the human could fulfill this scarcity condition. Moreover algae can be used for the production of ethanol. In this context, ethanol has wide market all over the world.Algae could be the best transport fuel in near future, continuous research activities have been tested. Technology related for transportation keeps on changing, none of the technology could have dominant in the world for more than 2-3 decays. Non-renewable fuels like coal, petrol should be replaced with renewable sources of energy which are easily available in all environment conditions. Such type of fuel obtained from algae would be more effective in both cost and quality. Due to the different type of technology and works, human people may suffer from different type of diseases and can become unhealthy. Algae species can be used for the medicines. With the wider research activities more number of diseases could be identified that can be treated with algae species without any side effects. During the production of one product, industry requires waters mainly for cleaning purpose and this water is drainage into river, lakes etc. Such type of water may contain harmful chemical substances and may detriote the original quality of water. For the maintence of water into natural form, algae could play a vital role. Due to the algae cultivation in high quantity, such type of waste water could be purified. Through the commercialization of algal cultivation, it leads for the protection of environment and minimizes risk factors. During breeding process, if we are able to insert genetic engineering and for the identification of superior quality algae then high lipid and rapid growing algae can be obtained.Algae helps for the combustion and fermentation of dead organisms, which inhibits bad, foul smell from them and gives pleasant smell. Through this environment could be natural all time. As during the consumption of every products, some byproducts are thrown out like engines emit smokes, if such fuels are made up of algae products than it won't harms environment much and contributes for sustainable development. Establishing the algae based industries helps to provide employment opportunities to many youths. Developing algae based industries leads for the stable and overall development in economic fields in the country.

4. Conclusion

Algae which covers the surface of aquatic region and terrestrial region, which is distributed all over the country, can provide beneficial effect to the citizens if it can be manipulated in organized way. Proper use of modern instrument for the processing of algae can give higher return too. Algal products are benefical, qualitative and quantative. Beneficial in a sense that for products which are obtained from the algae have some economic value. Quantative in a sense that algae are found in adverse climate, as a result algae as raw material never be diminished.Moreover algae grows faster. Algae related products have high amount of nutrient content as compared to other related products.Algae grows in unused area, due to which unused area can also give some profit, if used properly .As petroleum and diseal products which are major source of biofuel in present context, which needs a lot of effort to obtain such products. If the techniques which can process biofuel from the algae can be used, then not only it reduces the burden but also it will be qualitative, and can be easily available, which doesnot need any excavation as now.Consumption of algae in proper amount provides balance diet for the people and protects from diseases. Ultimately it helps in the purification of environment. Algae consume harmful substances secreted from different types of industry; absorb the carbondioxide and releases oxygen.

Alage are the major sources for eutrophication. During rainy seasons fertilizers like nitrogen, phosporous are eroded from the fields, and finally reaches to the river, lakes, and oceans. Algae get such fertilizers and they grow more rapidly, they starts to absorb the oxygen found in the water and redues the availability for aquatic organisms. As a result, aquatic organisms are hampered. Due to the presence of algae, natural environment is distrubed. Many varieties of algae are found, but in accordance with the diversity of algae very negligible research activities are performed as a result only few importances have been identifed. Presence of algae makes the way slippery as a result people may slip down

and can get hurt. Algae grown in the trees, rocks can weaken the trees, rocks and mineralization may proceed in rocks. Sometimes algae may hinder the growth of main crops like rice. Inhaled of algae in high quantity can may harm health of people.

Algae have many importance rather than demerits. International as well as national organizations should focus for the research activities. Biologist working on such field should be given priority make necessary arrangement for working. They should mainly focus for algae based products and think for sustainable development. Unemployed people can be given some training for cultivation of algae; hence they can utilize their leisure time and can generate some incomes. Government should focus on the algae based industry and cultivated algae can be processed for future use. Loans for algal industry should be made interest free or reduced as far as possible from the financial sector. Technical manpower having practical knowledge should be mobilized in different remote areas, where there is high possibility of emergence of algae, and they should provide practical knowledge to the residential people regarding uses, consumption, processing, post-harvest preservation etc. If country can progress in algae industry than it would contribute a lot in economic growth and development of nation.

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