Discipline Courses-I
Semester-I
Paper: Phycology and Microbiology
Unit-XII
Lesson: Applied phycology
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Introduction

<iframe width="560" height="315" src="//www.youtube.com/embed/3K5-t6ew10I" frameborder="0" allowfullscreen></iframe>

Video: Introduction to algae

Source: http://www.youtube.com/watch?v=3K5-t6ew10I

Applied phycology deals with the practical utilization of algae. It includes a diverse array of fields including algal culture and seaweed farming, the utilization of algae to make commercial products such as carotenoids, hydrocolloids,and pharmaceuticals, algae as soil conditionersto improve the physical qualities of the soil, in biofertilizers, the use of algae in the treatment of wastewater, algae as environmental indicators, in reducing CO_2 emissions,in renewable energy production and environmental bioremediation. The commercial production of microalgae and seaweeds and the products derived from them is a huge and well-established industry. Novel algal species along with newand improved yield of products and with effective bioremediation property are being continuously developed.Selection of algal genera and species and their genetic manipulation leads to a high production of desired chemicals or activity, hence creating a new biotechnological field.

This chapter is intended to give an introduction to the importance and uses of algae. After learning classification, life cycles and other microscopic details in the earlier chapters it is important to appreciate the roles that algae play in our world and how they affect the environment and lives of man, animals and plants.

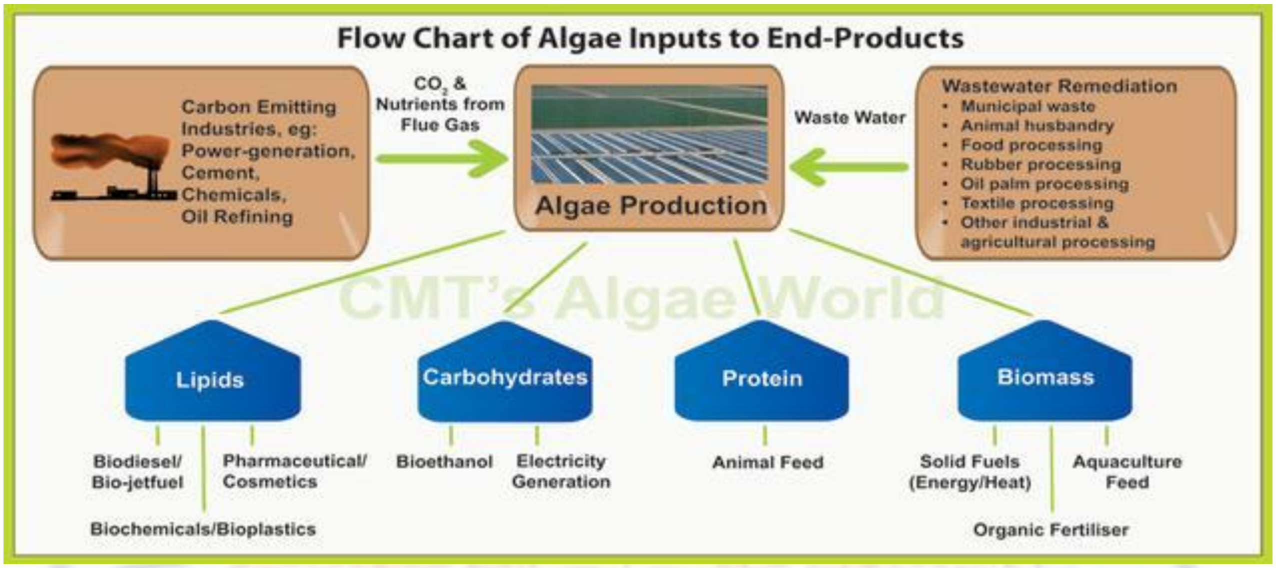


Figure: Algae prevent the harmful effects of wastewater to the environment, contribute to algal biofuels and reduce carbon emissions

Source: http://microbiologyfall2010.wikispaces.com/Algal+Biofuels

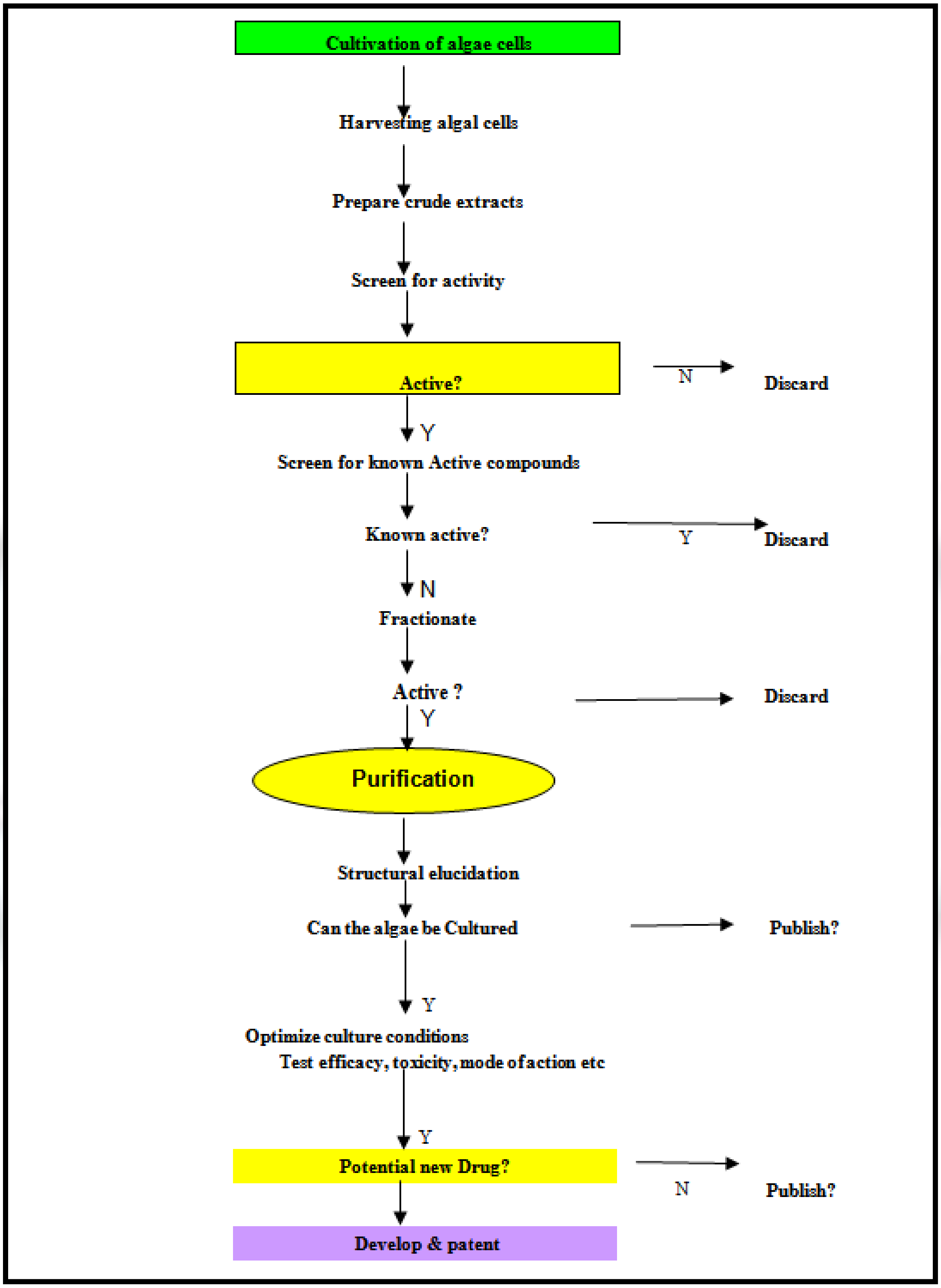


Figure: Schematic of the search for bioactive molecules from algae

Source: http://pubs.sciepub.com/jas/1/1/3/

Every alga (some 72,000+ species), may have commercial importance; however we know little about most of them and the importance of many algae has yet to be explored. Below is the list of some algal groups and genus, which are being utilized commercially or in which there is some current interest.

Cyanophyta

Spirulina(*Arthrospiraplatensis*): Spirulinais a filamentous alga and is produced in Japan, Taiwan, China, India, Thailand, USA for the health food market. It is also used as a source of phycocyanin and essential fatty acids.

Other Chrysophytes of interest are *Anabaena, Nostoc, Oscillatoria*.

Chlorophyta

Dunaliella salina: It is the star amongst the commercially important algae and is being grown commercially in Israel, India, Australia and China. It has a very high content of β-carotene which is the precursor of Vitamin A.

Figure: *Dunaliella salina* production plant in Australia, it is the largest production plant of algae in the world.

Source:http://www.bsb.murdoch.edu.au/groups/beam/BEAM-Appl4a.html

Chlorella spp.: Freshwater *Chlorella* is a carotenoid rich alga used for food supplements or health foods. Chlorella is also important as aquaculture feeds and for wastewater treatment. The mucilaginous species of *Chlorella* are used as soil conditioners.

Figure: Centre pivot ponds of *Chlorella* in Indonesia

Source: http://www.bsb.murdoch.edu.au/groups/beam/BEAM-Appl4a.html

Figure: *Chlorella* food supplements

Source: http://www.diphycal.com/en/chlorella-e/11-chlorella-green-gem.html

http://therealfoodrunner.blogspot.in/2012/08/chlorella-and-spirulina-algae-tabs_30.html

Haematococcus pluvialis: Haematococcus is a natural source of astaxanthin ('haematochrome'), a carotenoid. *Haematococcus* in its life history has a red colored resting stage followed by a green swimming stage followed over again by a red resting stage. The alga is harvested after the reddening cycle and the red pigment harvested.

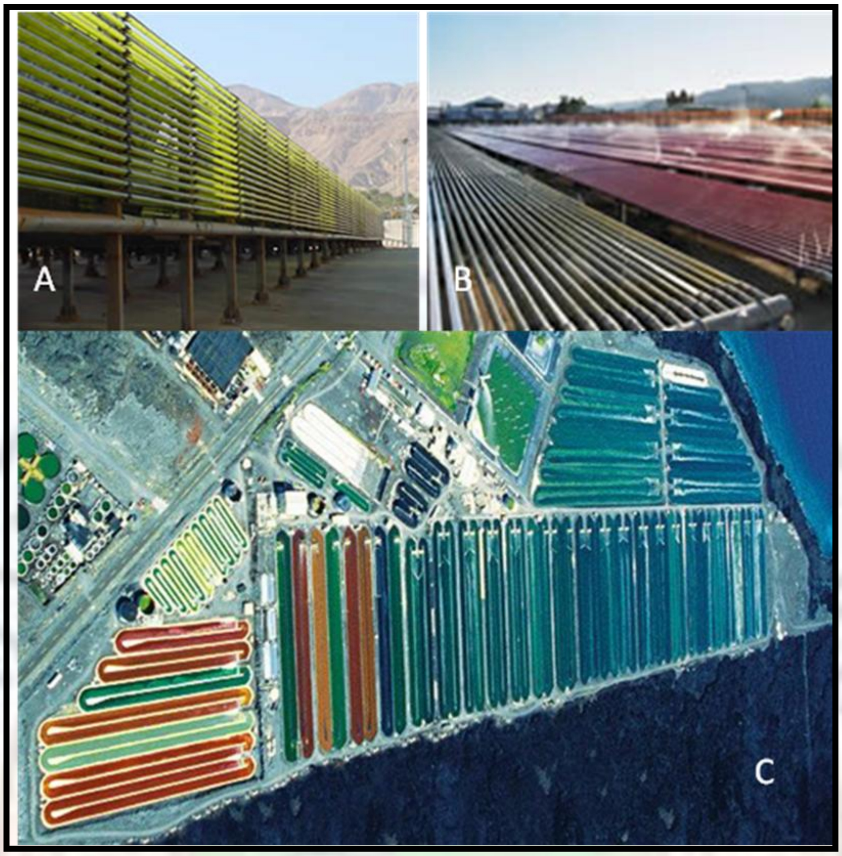


Figure:A, B *Haematococcus* production plant with tubular photobioreactors in Israel, C in Hawaii.

Source: http://atlanticgreenfuels.com/html/symposumdec16.html

*Botryococcus braunii:*This is the oil producing green alga. It produces large quantity of long-chain hydrocarbons.

Tetraselmis spp.: The genus is widely used in aquaculture facilities as feed for juvenile molluscs, shrimp larvae and rotifers. In addition, high lipid-containing strains have potential to be used in biofuel production.

Some other Chlorophytes of interest are *Scenedesmus, Nannochloropsis, Chlamydomonas, Euglena* and *Asteromonas.*

Phaeophyta

Macrocystis pyrifera: It is commonly known as giant kelp. Giant kelp is a source of alginate and minerals such as iodine and potassium.

Laminaria: It is a source of iodine and mannitol. Laminaria is of food value and prevents fat absorption hence promotes weight loss.

Other Phaeophytes of interest are *Sargassum, Undaria, Turbinaria, Ascophyllumnodosum* etc.

Rhodophyta

Porphyridium: It is a source of sulphated polysaccharides, essential fatty acids (arachidonic acid) and phycoerythrin.

Other Rhodophytes of interest are *Porphyra*, *Chondruscrispus* etc.

Chrysophyta

Isochrysis galbana: It is an important aquaculture feed.

Some other Chrysophytes of interest are *Nitzschia, Cylindrotheca, Amphora* and *Chaetoceros.*

Country	Commercial producers	Algae/Products
India	Parry Nutraceuticals	*Spirulina, Dunaliella, Haematococcus*
Japan	Dai Nippon Ink.	*Spirulina*
Taiwan	Taiwan Chlorella Corp. + others	*Chlorella*
China	Tianjin Lantai Biotechnology	*Dunaliella*
Australia	Cognis Nutrition & Health Aquacarotene Ltd.	*Dunaliella*and β-carotene β-carotene
U.S.A	Cyanotech Inc. Earthrise farms R+A Plant/soil Inc.	*Spirulina, Haematococcus*; phycobilins, ß-carotene *Spirulina* Soil conditioners and fertilisers
Europe	French Petroleum Inst. Montedison Co.	*Spirulina, Porphyridium* etc. *Spirulina*

Israel	NatureBeta Algatech	*Dunaliella* *Haematococcus*

Algae in biotechnology and industry:

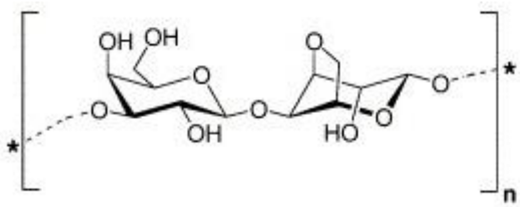
1. Polysaccharides:

Majority of the natural polysaccharides utilized in industry come from algae and microbes. The use of algal polysaccharides is more common in the food industry and pharmaceutical industry because of the unique nature of algal polysaccharides. The main uses of these polysaccharides in food industry are as gelling agents, thickeners, stabilizers, and emulsifiers. They are also used in cosmetics and in paper industries. Agar and carrageenan are the two major polysaccharides extracted from red algae. Alginates or alginic acid are extracted from brown algae. It has been estimated that seaweed extracts add to an annual turnover of several hundred million dollars.

(i) Agar- agar: Agar is a dried or gel like non-nitrogenous substance extracted from red algae. The first commercial agar was produced in 1670 in Japan, which is still one of the largest suppliers agar in the world. The beginning of agar industry in India is around 1965, and today more than six plants are in operation of which Ahmedabad alone produces about 100 kg of agar per day. The present manufacturing capacity of Indian industries is about more than 70 tons per year.

Composition: It is a polysaccharide which accumulates in the cell wall of red algae along with cellulose. Agar is a mixture of agarose, the linear polysaccharide and agaropectin, a heterogenous mixture of small molecules. Agar contains galactans, α-galactose and β-galactose residues with a little amount of sulfate esterification.

Sources: The main sources of agar are thalli of *Gelidium, Gracilaria* and *Gigartina*. Agar is a gelatinous, clear, nitrogen free extract from the above mentioned genera of red algae. The extract is a gel containing galactose and a sulphate. Its melting point is about 90-100ºF. At lower temperatures it changes into a solid.



Agar: β-(1-3)-D and α-(1-4)-Llinked galactose residues

Uses of Agar:

(i) Agar is used as a gelling and thickening agent in food industry in the preparation of puddings, jams, jellies etc., as a stabilizer for mayonnaise and as emulsifying agent in ice-creams.

(ii) In the preparation of **culture media** in laboratories as a solidifying agent for culturing microorganisms such as bacteria, algae, fungi and in tissue culture techniques.

(iii) It is used as a laxative to treat chronic constipation.

(iv) As a stabilizer in cosmetics for the preparation of ointments, creams and emulsions.

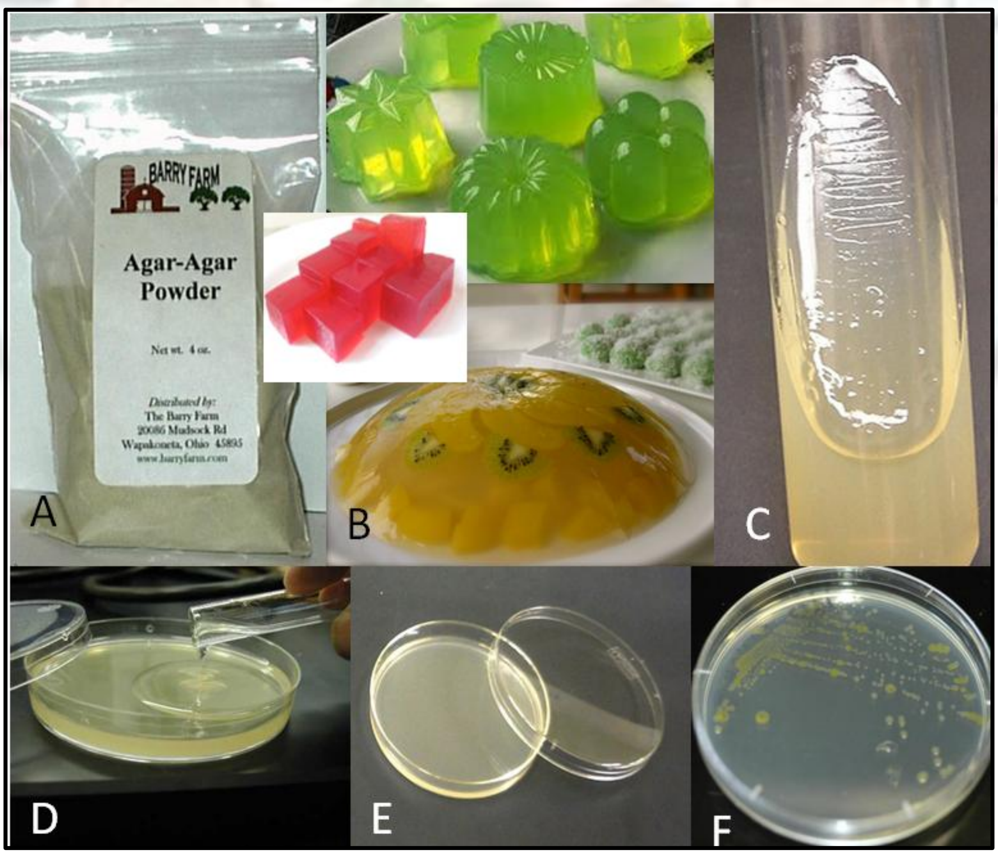
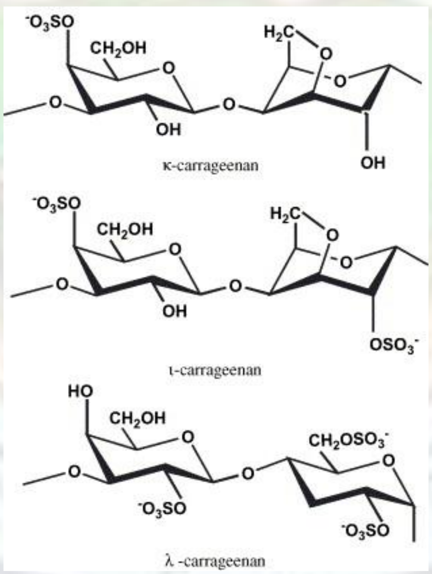


Figure: Agar agar and its uses in food industry and laboratory

Source:
http://www.barryfarm.com/nutri_info/thickeners/agar.htm,http://commons.wikimedia.org/wiki/File:Agar_Plate.jpg,http://www.google.co.in/imgres?imgurl=&imgrefurl=http%3A%2F%2Fwww.flickr.com%2Fphotos%2Fmedmicro%2Fsets%2F72157604437358685%2Fdetail%2F&h=0&w=0&sz=1&tbnid=UR4OLHmjAC0nvM&tbnh=194&tbnw=259&zoom=1&docid=FL1hqlIvI00FdM&ei=PXhAUuH6A43OrQfGyIHICg&ved=0CAEQsCU

(ii) Carrageenan: Carrageenan are linear sulphated polysaccharides present in the cell walls of red algae.

The chief source of Carrageenan is a red alga *Chondrus crispus* (Irish moss) and to a lesser extent *Gigartina*. Carrageenans are commonly used in food industry for their thickening, gelling and stabilizing properties. Mainly three varieties of carrageenans have been recognized on the basis of their degree of sulfation. These are: κ- (Kappa) carrageenan (characterized by one sulfate per disaccharide), ἰ- (iota) carrageenan (two sulfates per disaccharide) and λ- (lambda) carrageenan (three sulfates per disaccharide).



Uses of carrageenan:

1. It is used in food industry mainly in confectionary and bakery. It is used in custard powders, jelly production, milk puddings, syrups, sauces, soups, ice-creams etc.

2. Carrageenan is used for bronchitis, coughs and intestinal problems.

3. It is also used as an emulsifier, thickening agent, binder and stabilizer in medicines, foods and toothpastes.

4. It is used in paper and textile industry.

Figure: Carrageenan and its commercial utilization

Source: http://farm-industry.blogspot.in/2010/10/carrageenan-most-potential-product-from.html,http://www.google.co.in/imgres?imgurl=&imgrefurl=http%3A%2F%2Fwww.functionalps.com%2Fblog%2F2011%2F11%2F11%2Fcarrageenan-inflammation-cancer-immunity%2F&h=0&w=0&sz=1&tbnid=8keasG6lu168DM&tbnh=263&tbnw=192&zoom=1&docid=CKhW_uxsNsOF-M&ei=5nhAUtyfH4KqrAfVroDICQ&ved=0CAEQsCU

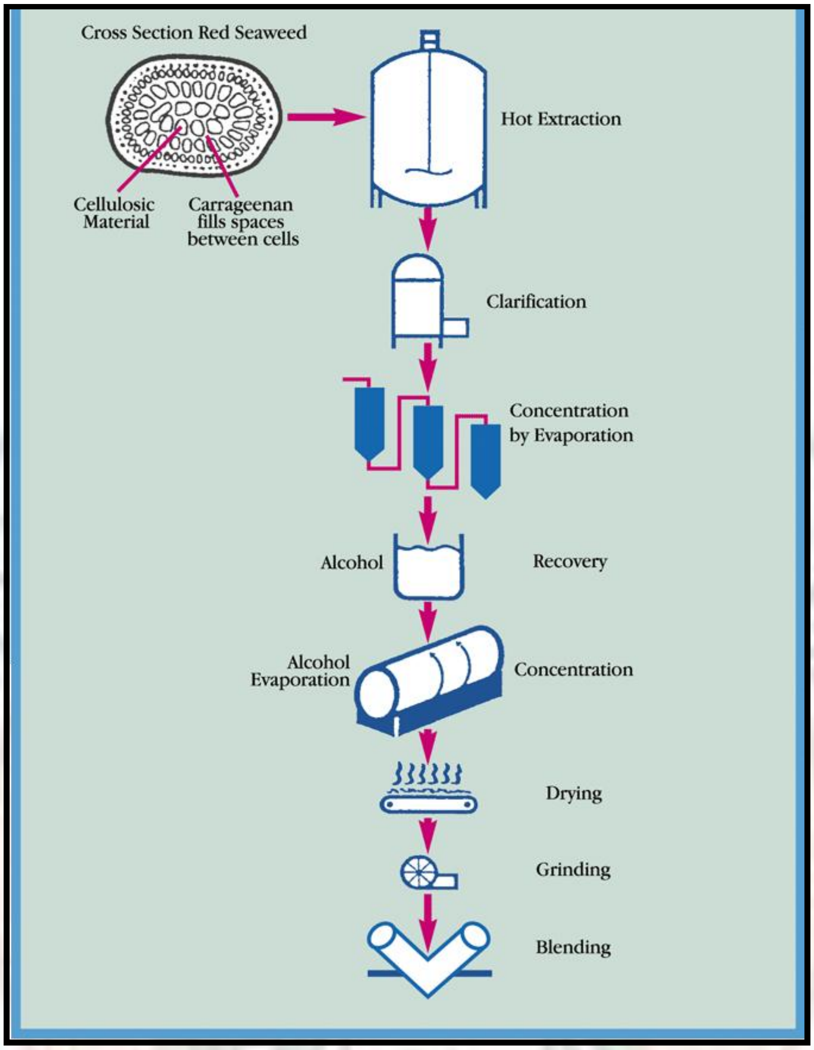


Figure: Manufacturing process of carrageenan

Source: http://www.fmcbiopolymer.com/Food/Ingredients/Carrageenan/Manufacturing.aspx

(iii) Alginic acid: Alginic acid is an anionic polysaccharide present in the cell walls of brown algae.

Sources: The brown algae *Fucus, laminaria, Macrocystis, Sargassum*

Uses of alginates:

1. Alginates are used as thickeners in fruit and cream fillings.

2. Alginates are used as fillers in the manufacture of tablets, pills and lozenges.

3. Sodium alginate is used as a slimming agent.

4. Calcium alginate has its use in making capsules.

5. Alginates are used as thickening agent in the preparation of ointments, creams, lotions etc. They are also used as foam stabilizers in soap industry.

6. Alginates are used in paper industry to increase the gloss of the paper.

2. Carotenoids:

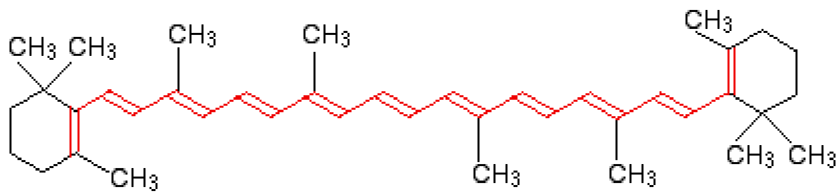
Carotenoids are naturally present organic pigments responsible for the different colours of vegetables, fruits and other plant parts. Carotenoids are usually yellow to red pigments. **Carotenoids** are grouped into **carotenes** (Oxygen-free hydrocarbons) and **xanthophylls** (oxygen derivatives of carotenes). Both carotenes and xanthophylls are present in algae.The carotenoids primarily function as photoprotective pigments and as accessory light harvesting pigments. Increase in certain carotenoid pigments in most algae can be correlated to various types of stress conditions which can be easily seen as occurring in nature. Algae that accumulate large quantities of carotenoids usually demonstrate the ability to survive under stress conditions for a prolonged period. These algae are promising candidates for carotenoid production. Numerous stress conditions to induce carotenoid production can be nitrogen deprivation, phosphate limitation, desiccation, high CO_2 concentration etc. The consumption of carotenoid rich diet has been correlated with a lower risk for several diseases such as cataracts, arteriosclerosis, multiple sclerosis and cancer.

Commercially important carotenoids are β-carotene, astaxanthin, lutein, zeaxanthin and lycopene which are used in pharmaceuticals, food colourings and cosmetics. The most important carotenoids produced by algae are β-carotene by *Dunaliella salina* along with astaxanthin by *Haematococcus pluvialis*. Accumulation of carotenoids occurs under conditions of nitrogen deficiency, high irradiance or salinity. This is particularly true in *Dunaliella* where β-carotene accumulates between thylakoids in the chloroplast, and *Haematococcus*, where astaxanthin accumulates in lipid globules outside the chloroplast. Haematochrome is a general term for these carotenoids. Accumulation of haematochromes colour the cells orange or red, with haematochrome accumulating upto 8-12% of the cellular contents in *Dunaliella*. Animals cannot synthesize carotenoids and they acquire the pigments through the food chain from primary producers. Haematochromes are responsible for the coloring in fish, crustaceans and birds (such as the pink flamingos).

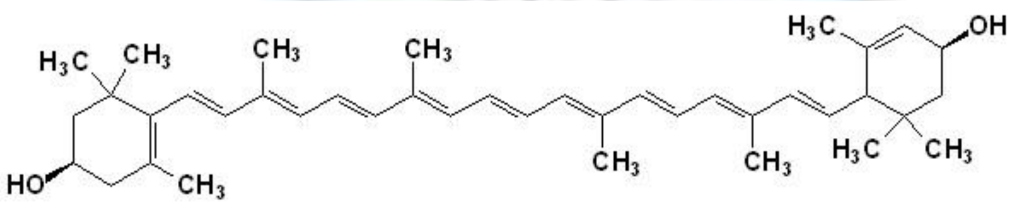
Importance:

1. **β-carotene** is an essential nutrient It is used as a natural food colouring agent, as additives in cosmetics and also as a health food. β-carotene is also used in soft-drinks, cheese, butter or margarines. It is well considered as safe and certainly has beneficial health effects because of its pro-vitamin A activity.

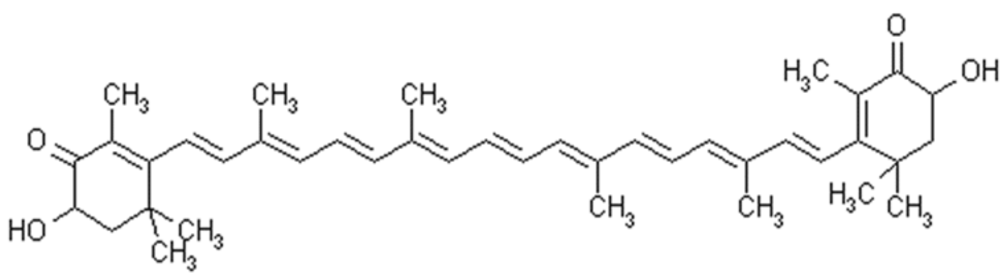
2. **Astaxanthin** also has numerous health benefits which include enhancing eye health, increasing muscle strength and endurance, skin protection from premature ageing UVA damage and inflammation, immune function and regeneration. Astaxanthin also protects corpse tissues from oxidative damage. Astaxanthin has a capacity to fight free radicals many times than that of vitamin E.



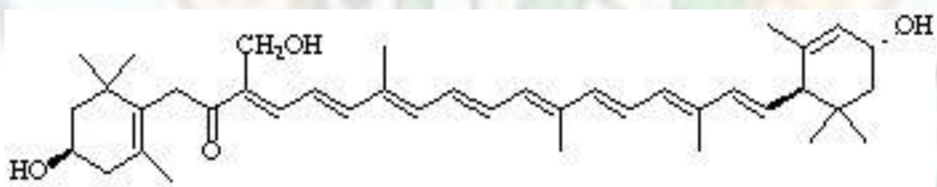
β carotene



Lutein



Astaxanthin



Siphonoxanthein

Figure: Carotenoids structure: Carotenoids are grouped into carotenes (Oxygen-free hydrocarbons) and xanthophylls (oxygen derivatives of carotenes). Hence β carotene and lutein are carotenes and astaxanthin and siphonoxanthin are xanthins.

Source:http://eng.ege.edu.tr/~otles/antioxidants/pages/antioxidants_that_are_naturally_found_in_foods.htm

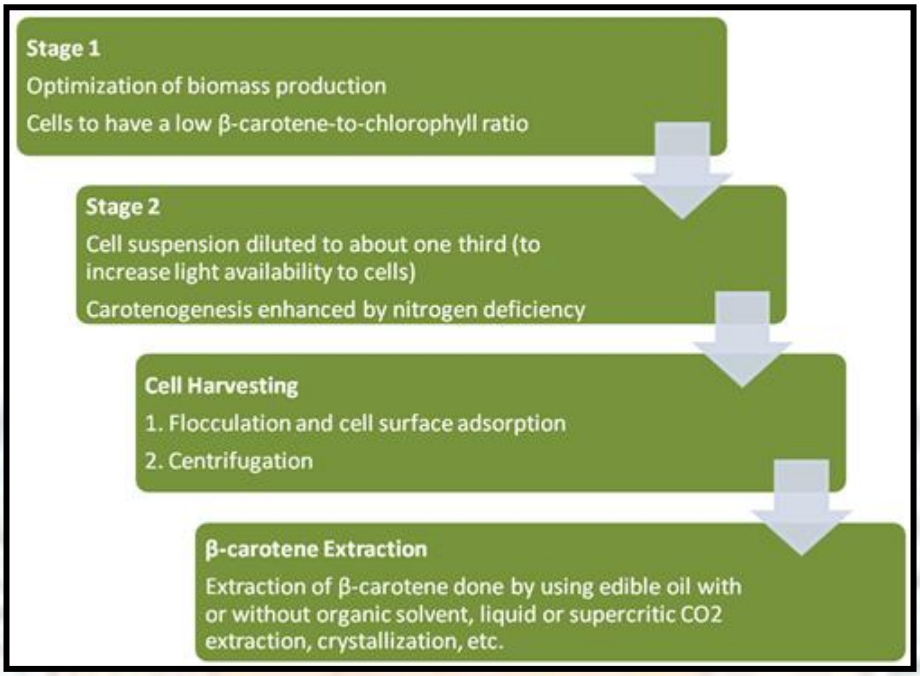


Figure: Beta-carotene Production and Extraction from *Dunaliella salina*

Source: http://www.oilgae.com/non_fuel_products/betacarotene.html

Figure: Beta carotene and astaxanthin from algae

Source:http://miraclenutritionalsupplements.com/store/pages.php?pageid=67,http://www.vitaminlife.com/product-exec/PNAME/Natural-Beta-Carotene-25-000-IU--Algae-Source-/product_id/14044,http://caoh.com/liquid-vitamin-blog/tag/beta-carotene/

3. Phycobiliproteins:

In addition to chlorophyll and carotenoid pigments (lipophilic), Cyanobacteria, Rhodophyta and Cryptomonads contain phycobiliproteins. The plastids of Chlorophyta, Charophyta and land plants lack the phycobilin accessory pigments and thylakoid bound phycobilisomes (a characteristic pigment of cyanobacteria, red algae and glaucophytes). Phycobilins are water-soluble pigments and are associated with a protein moiety. Hence phycobiliproteins are formed by a covalent linkage of a protein backbone with phycobilins (tetrapyrrole chromophoric prosthetic groups). These phycobiliproteins are main components of an assemblage of antenna pigments - the phycobilisomes. The most important natural sources of phycobiliproteins are:

1.The cyanobacterium *Spirulina* for phycocyanin

2. The rhodophyte *Porphyridium* for phycoerythrin

Phycocyanin is used as a natural colouring agent in food products for ex. candies, jellies, ice creams, dairy products, soft drinks as well as in cosmetics such as lipsticks. Several pharmacological properties have been attributed to phycocyanin such as antioxidant, anti-inflammatory and neuroprotective.

Phycoerythrins are commonly used in fluorescence applications, as highly sensitive fluorescence markers for clinical diagnosis and immunoassays such as for labeling antibodies in multicolour immunofluorescence or in fluorescence-activated cell-sorter (FACS) analysis.

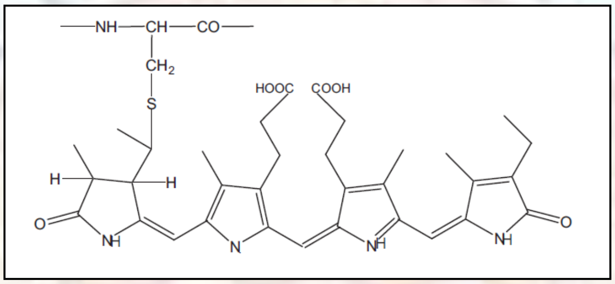


Figure: Structure of Phycobillin

4. Lipids and fatty acids:

Higher plants and animals do not have the enzymes to synthesize long chain polyunsaturated fatty acids (PUFAs) of more than 18 carbons. These can be synthesized by microalgae which supply whole food chains with these suplements.

In green algae unsaturated C16 and C18 fatty acids predominate, while in red algae, C20 polyenic acid dominate. The fatty acids of brown algae fall in between green algae and red algae. Some microalgae synthesize fatty acids with particular interest, namely γ-linolenic acid, arachidonic acid, eicosapentaenoic acid, docosahexaenoic acid etc.

Inclusion of these long chain fatty acids in daily diet is highly recommended. Majority of health and nutrition organizations recommend the addition of docosahexaenoic acid (DHA) in infant formula. Presently DHA is the only commercially available algal PUFA. Some species of *Phaeodactylum, Isochrysis, Porphyridium, Nitzschia, Nannochloropsis* and Spirulina have proven industrial production potential of eicosapentaenoic acid (EPA), γ-linolenic acid (GLA) and arachidonic acid. DHA is an ω3 fatty acid and is a major structural component of the brain, retina and heart tissue. DHA is essential for the proper development of brainand eyes in the infants and also supports cardiovascular health in adults. It is also found infish, organic meat and in breast milk.OmegaTech and Martek companies in USA utilize *Schizochytrium* to produce an oil known as DHA Gold. The oil is presently used in food and beverages as a dietary supplement for adults, in foods for pregnant women and also finds applications in cardiovascular health. Nutrinova process in Germany utilize Ulkenia sp. to produce an oil named as DHActive.

Figure: PUFA (DHA) from algae

Source: http://www.medscape.org/viewarticle/576960_2,http://www.starrwalker.com/dha-from-algae,http://www.nutraingredients-usa.com/Manufacturers/Nordic-Naturals-taps-into-demand-for-fishless-fish-oil-with-new-algal-EPA-DHA-products

5. Sterols and tocopherols:

Sterols or steroid alcohols, are a subgroup of the steroids and an important class of organic molecules. Marine algae contain sterols like sitosterol, fucosterol, cholesterol, chalinestrol and 2,2-dehydrocholesterol. Sterols are essential to the structure and function of cell membrane and also act as precursor to fat-soluble vitamins and steroid hormones. Many sterols have anticancer activity. Cyanobacteria were earlier considered to be devoid of sterols but recently using refined techniques complex mixtures of sterols have been isolated in very small amounts form most of the blue green algae and the variety of sterols was remarkable. Chlolesterol was found in Spirulina and some other species were found to contain C28 and C29 as their principal sterol. Fucosterol is the principal sterol of Phaeophyta (brown algae). Most Phaeophyta also have traces of cholesterol along with biosynthetic precursors of fucosterol.Rhodophyta (red algae) contain cholesterol as their principal sterol, though several species have large amounts of desmosterol and 22-dehydrocholesterol. A few Rhodophyta have traces of C-28 and C-29 sterols. The sterols of Chlorophyta (green algae) are much more diverse and complex compared to the sterols of other groups of algae. While the Phaeophyta and Rhodophyta have one primary sterol, most of the Chlorophyta have mixture of sterols as also observed in higher plants. The Chlorophyta contain sterols such as poriferasterol, chondrillasterol, 28-isofucosterol, ergosterol, cholesterol, methylenecholesterol etc. Sterol composition might be of use in the systematics of Chlorophyta. Primitive orders of Chlorophyta e.g. The Chlorodendrales (*Tetraselmis maculata, T. tetrathele, T. chui* and *T. suecica*) contain 24 methylcholesterol and 24 methylenecholesterol. Volvocales, Chlorococcales orders of Chlorophyta have many species containing ergosterol.

Tocopherols are a family of chemical compounds havingvitamin E activity. Tocopherols are present in high amounts in algae.*Euglena* microalga has the maximum tocopherol content among the various genera of algae, yeast and molds tested. Tocopherols have been reported from several algal genera i.e. *Anabaena variabilis, Isochrysis galbana, Chlorella protothecoides, Caulerpa lentillifera, Chlamydomonas reinhardtii, Eucheuma cottonii, Fucus serratus, Nannochloropsis oculata, Phaeodactylum tricornutum, Laminaria ochroleuca*

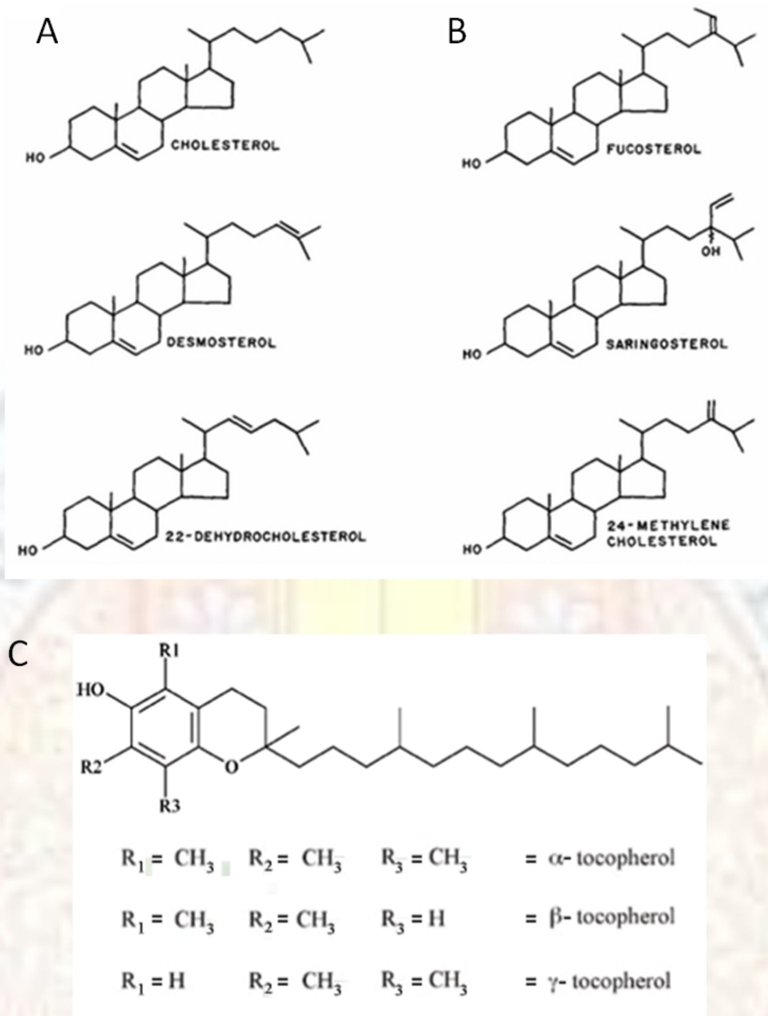


Figure: Structure of sterols and tocopherols

Source: http://link.springer.com/article/10.1007%2FBF02531327#page-1

6. Glycerol and mannitol:

Glycerol and mannitol are sugar alcohols found in the cell sap of brown and red algae. Mannitol is obtained form species of *Laminaria*, *Ecklonia* and *Fucus*. Large quantities of glycerol and mannitol are produced from other raw materials. Glycerol is used in cosmetics, food additives, plastics and pharmaceuticals etc. Mannitol has a variety of uses in pharmacy, paint, varnish, leather, paper, explosives and plastics.

7. Amino acids and proteins:

Domoic acid and other amino acids are obtained form algae. The high protein content of various microalgal species is one of the main reasons to consider them as an unconventional source of protein. Spirulina (*Arthrospira platensis*) is high protein source (65-71 percent protein). It has got more protein content compared to the conventional protein sources such as meat and other plant-protein sources such as beans, lentils,nutsand soy products.
Spirulina is also a good source of vital amino acids and minerals. Only two tablespoons of Spirulinacan be used as a protein substitute for a meal. Algal proteins are of high quality, comparable to conventional vegetable proteins due to their content of essential amino acids, which mainly determine the nutritional quality of a protein source. The amino acid profile of various algae are compiled in table and compared with some conventional food items along with a reference pattern of a well-balanced protein, as recommended by WHO/FAO.

	Leu	Val	Arg	Lys	Ile	Phe	Thr	Met	Try	His
WHO/FAO	7	5		5,5	4	6,0		3,50	1	
Egg	**8,8**	**7,2**	6,2	5,3	**6,6**	**5,8**	**5**	**3,2**	**1,7**	2,4
Meat	7,8	5,3	6,6	**8,2**	5,1	4,2	4,5	2,4		**3,2**
Milk	9,2	5,7	3,3	7,8	4,3	5,6	4,5	2,5		2,6
Soybean	7,7	5,3	**7,4**	6,4	5,3	5	4	1,3	1,4	2,6
Fish-meal	4,48	2,77	3,82	4,72	2,66	4,35	2,31	2,31	0,57	1,45
Chlorella vulgaris	8,8	5,5	6,4	8,4	3,8	5	4,8	2,2	**2,1**	2
Dunaliella bardawil	11	5,8	7,3	7	4,2	5,8	5,4	2,3	0,7	1,8
Scenedesmus obliquus	7,3	6	7,1	5,6	3,6	4,8	5,1	1,5	0,3	2,1
Arthrospira maxima	8	6,5	6,5	4,6	6	4,9	4,6	1,4	1,4	1,8
Spirulina platensis	9,8	**7,1**	7,3	4,8	**6,7**	5,3	**6,2**	**2,5**	0,3	2,2
Tetraselmis suecica	9,3	5,6	7,6	9,8	4,1	5,9	5,3	1,5		**2,5**
Isochrysis galbana	10,5	6	**8,7**	12,1	4,9	6,1	6,1	0,7		**2,5**
Dunaliela tertiolecta	**10,7**	5,3	7,2	**13,6**	4,2	**6,6**	2,6	0,8		**2,5**
Chlorella stigmatophora	9,3	5,7	8,6	13,4	3,8	5,5	4,9	1,4		2,3

Figure: Amino acid Profile of various algae compared with usual protein sources (g per 100 protein).

Source:http://www.algae4feed.org/admin/files/data/imagens/1274457051_Feed_AminoAcidsTable.jpg

8. Antibiotics from algae:

A variety of algae have been screened for antibiotics and other pharmacologically active compounds. A large number of active compounds with antibacterial and antiviral activity have been isolated from algae. The *Chlorella* spp., *Chlamydomonas* spp., *Scenedesmus* spp., *Microcystis aeruginosa* and *Euglena viridis* are the main microalgae that produce antimicrobial substances. Rhodomelol and methylrhodomelol have been isolated from *Polysiphonia lanosa*. *Dunaliella primolecta* have been found to contain a number of different antibiotic substances. Some bioactive antimicrobial compounds isolated from various algal species are listed below.

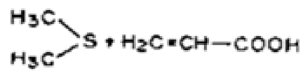
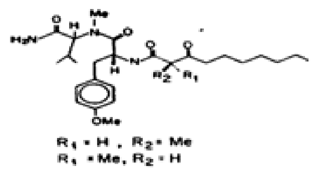
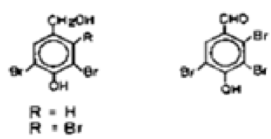
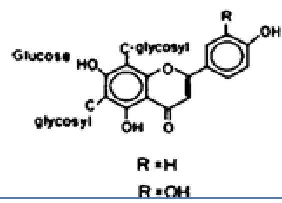
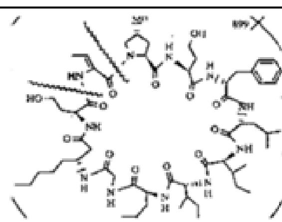
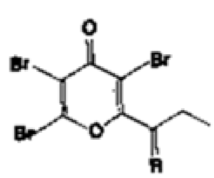
Algae	Compounds	References
	Sulfur compounds	
Phaeocystis poucht	 Acrylic acid Gram-negative organisms	Richmond (1986)
green algae *Chara globularis*		Richmond (1986)
Blue green alga *Lyngbya mjuscula* *L. gracilis*		Richmond (1986)
Calothrix brevissima	Antifungal 	Richmond (1986)
Chlorophyta *Nitella hookeri*		
	Antifungal	
Blue green alga *Hormothamnion Enteromorphoides*	 Hormothamnin A Antimicroal to *Bacillus subtills*	Gerwick *et al.* (1992)
Delisea fimbriata	Cytotoxic to several cancer cell lines  Gram-negative organisms R= Br or O	Baker and Josph (1984)

Figure: Antibiotics from algae

Source: http://pubs.sciepub.com/jas/1/1/3/

9. Algae in cosmetics:

Some microalgae are well recognized in the skin care souk, the main ones are *Arthrospira* and *Chlorella*. Microalgae extracts are mostly found in face and skin care products such as anti-ageing creams, emollients, in peelers or peel off masks, refreshing and regenerant care products etc. Microalgae are also used in sun protection products and hair care products. For example:

1. A protein-rich extract obtained from *Arthrospira* helps in repairing the signs of skin aging, prevents the formation of fine lines on skin and exerts a tightening effect (Protulines, Exsymol S.A.M., Monaco).

2. An extract from *Chlorella vulgaris* (Dermochlorella, France) stimulates collagen synthesis in skin, thus supporting tissue regeneration and wrinkle reduction.

3. An ingredient from *Nannochloropsis oculata* has excellent skin-tightening properties (Pepha-Tight, Switzerland)

4. An ingredient from *Dunaliella salina*, shows the ability to stimulate cell proliferation and positively influences the energy metabolism of skin (PephaCtive, Switzerland).

Figure: Algae in cosmetics

Source: http://en.hairdresser-models.eu/gallery/cosmetics/algae-cosmetics.html

http://www.docstoc.com/docs/45738587/A-new-dimension-in-algae-based-cosmetics-base-cream

http://www.fastcompany.com/1735480/how-algae-biofuel-company-ended-cosmetics-business

http://www.made-in-china.com/showroom/rhabbit/product-detailVeiJPyLzHfWq/China-Algae-Moistening-Care-Series.html

10. Vitamins and minerals from algae:

Algae are a valuable source of vitamins A, B_1, B_2, B_6, B_{12}, C, D, E, biotin, folic acid, nicotinic acid and pantothenic acid. *Chondrus crispus* and *Porphyra liciniata* are excellent source of Thiamine. Diatom *Nitzschia* is a rich source of vitamin A. *Ulva*, *Enteromorpha, Porphyra, Laminaria* and *Chondrus crispus* contain Vitamin B. Vitamin C is found in *Ulva*, *Enteromorpha,* and *Undaria*. Red and green algae are rich sources of vitamin B and C. Vitamin D occurs in brown algae. The vitamin content of the alga depends on its genotype, growth phase, nutritional status and the light intensity. Hence the vitamin content is amenable to manipulation by altering the culture conditions, by strain selection or else genetic engineering. Vitamins content of a cell fluctuates with environmental factors, the harvesting process and the biomass drying technique. Algae also have a fair mineral content (e.g. Na, K, Ca, Mg, Fe, Zn and trace minerals). The high levels of Iron and vitamin in Spirulina, makes it particularly suitable as nutritional supplement. Iodine is found in marine algae in the form of sodium and potassium iodide. Iodine is commonly obtained from *Laminaria.* Most of the important minerals such as iron, copper, zinc, cobalt, manganese, vanadium, boron are present in high amount in seaweeds.

Figure: Vitamins and minerals from algae

Source:http://www.hygeiahealthmarket.com/products-vitamins.asp,http://www.gardenoflife.com/Products-for-Life/Vitamin-Code/Targeted-Nutrient-Formulas/RAW-Calcium.aspx, http://www.algaecal.com/

11. Biofuel from algae:

<iframe width="560" height="315" src="//www.youtube.com/embed/IxyvVkeW7Nk" frameborder="0" allowfullscreen></iframe>

Source: http://www.youtube.com/watch?v=IxyvVkeW7Nk

The energy crisis, world food crisis and climate change have raised the interest in algal farming to produce vegetable oil, biodiesel, bioethanol, biogasoline, biomethanol, biobutanol, and other biofuels. It has been found that algae is an ideal production system for renewable biofuels because it is easy to grow in fresh water, sea water or brackish water, and consume CO_2 as their carbon source to convert solar energy into chemical energy. Algae fuel (algae biofuel) is a substitute to fossil fuel which uses algae as its resource. Harvested algae release CO_2 when burnt similar to fossil fuel but unlike fossil fuel, the CO_2 is used by the growing algae and other sources of biofuel. Several government agencies and companies are funding efforts to make algae fuel production commercially viable.

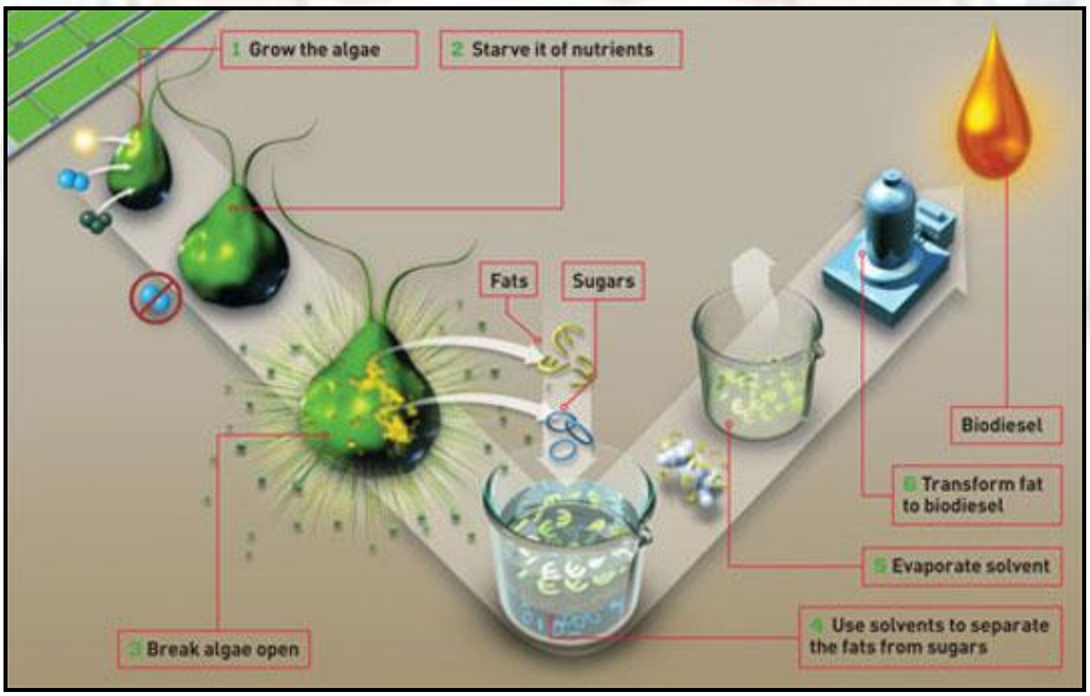


Figure: Production of biodiesel from algae

Source:http://www.dailytech.com/Military+Biofuel+Costs+Slashed+Thanks+to+Massive+Navy+Purchase/article23454.htm

Presently most of the biofuel production is from the fermentation of sugar produced from grains by conventional yeast strains, or on transesterification by acid/alkali or enzyme based catalysts. It is the first generation of biofuel production which is thought to have negative impacts on food security and controversial energy balance. Second generation biofuels involve biological processing of (ligno) cellulosic biomass to overcome the fuel vs. food dilemma.

3rd and4th generation biofuels use algae to create renewable fuels: the former is basically processing of algae biomass for biofuel production, while the latter is about metabolic engineering of algae for producing biofuels from oxygenic photosynthetic organisms. Microalgae are of immense interest in biofuel production and in present day energy scenario because of their fast growth along with relatively high lipid and carbohydrate content. All these properties make them a brilliant source for biofuel production such as biodiesel, bioethanol and biomethane.

Gaseous biofuel: H_2 is produced by a variety of algal strains. Genetic engineering has a very important role in the modification of microalgae for H_2 production. Examples of microalgae used for H_2 production are *Chlorella vulgaris*, *Chlamydomonas reinhardtii* and *Synechocystis.*

Algal ethanol and butanol: Algal ethanol and butanol is produced from genetically modified *Synechococcus* and *Synechocystis*.

Algal biodiesel: Fatty acids serve as precursors for biodiesel production. Some microalgae accumulate triacylglycerols (TAGs) as high as 30-60 % of their dry cell weight.

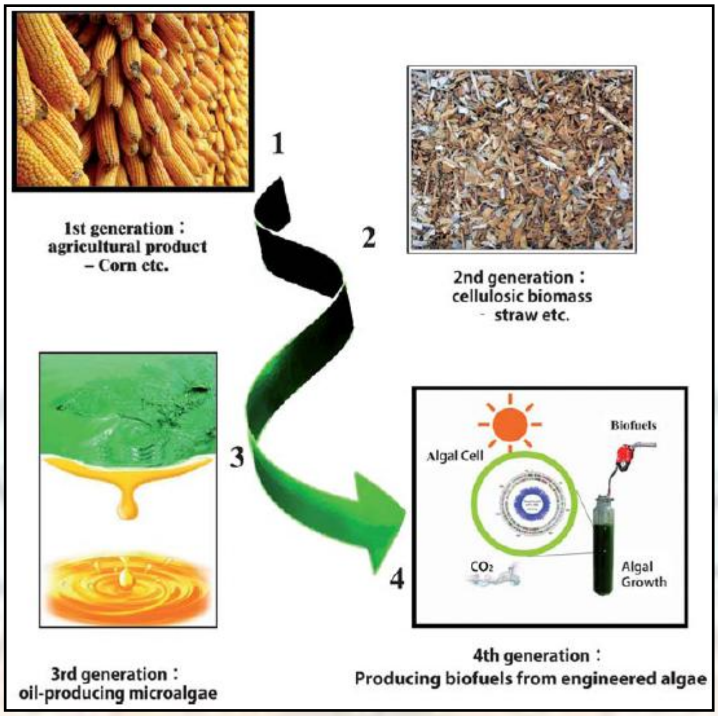


Figure: Various generations of biofuel production: 3rd and 4th generation are from algae

Source: Jing Lu *et al.* 2011

Figure: First Algae powered car

Source: http://inhabitat.com/first-algae-powered-car-attempts-to-cross-us-on-25-gallons/

12. In paints and coatings:

Certain algal cultures produce some fatty acids which are suitable for the production of coatings, paints and other lacquer products. These coatings are manufactured by AkzoNobel. This new method of manufacture of paints and coatings is more environmentally-friendly compared to the other methods currently in use in which mineral oil is used as raw material. In addition, the algae are vast and inexhaustible resource. Algal cultures can double their weight within a day. This makes them major biomass producers. This biomass can be used by energy companies to their advantage.

Role of algae in the environment and pollution control

1. In Wastewater treatment:

Algae are used as biofilters to eliminate nutrients and pollutants from wastewaters. Use of algae in the wastewater treatment process to remove phosphates and nitrates is a sustainable technology which reduces the further need for chemical fertilizers. Harvested algae can be used for commercial purposes, such as for pigments and animal feed, while cleaning domestic waste water at the same time.

<iframe width="560" height="315" src="//www.youtube.com/embed/GxTmw_PzJOw" frameborder="0" allowfullscreen></iframe>

Video: Use of algae in wastewater treatment

Source: http://www.youtube.com/watch?v=GxTmw_PzJOw

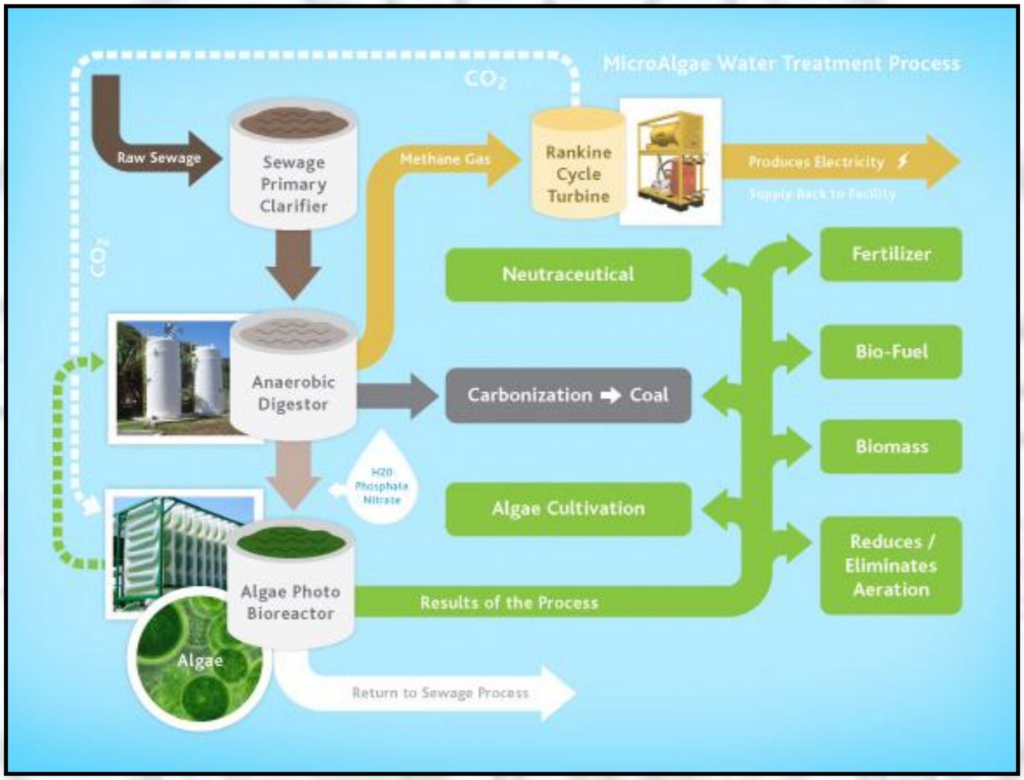


Figure: Microalgae water treatment process

Source: http://www.emcchawaii.com/services.html

What is sewage and can it be biologically reclaimed?

Sewage comprises of water borne domestic and industrial wastes of the community. It contains organic and inorganic parts in dissolved or suspended stage. Generally, sewage is discharged into rivers, lakes or other water bodies. It can also be disposed of by discharging it on land, where it will partly evaporate and partly percolate. Direct disposals of sewage can cause serious risks to health, along with wastage of valuable resources of manure. They lead to the emission of bad odours and spread of enteric diseases. It is therefore necessary to pre-treat the sewage before disposal. Sewage reclamation is done to render the organic matter ineffective and harmless. Sewage reclamation is mainly an aerobic process and oxidation of organic compounds of sewage is brought about by certain bacteria. Lack of oxygen prevents their complete oxidation. Algae photosynthesis and release oxygen if light is available to sewage oxidation tanks. This oxygen helps in complete oxidation of the sewage. The algae which thrive under such conditions are *Euglena, Chlamydomonas, Pandorina, Chlorella, Scenedesmus* etc. The effective mineralization of these organic compounds can be achieved only by their oxidation into simple and soluble inorganic compounds, which is essentially a biological process. For this, an abundant supply of oxygen is required to meet the respiratory requirements of the aerobic bacteria and the protozoa involved in this process. Oxygen required to oxidize the organic waste is obtained by encouraging the growth of photosynthetic green algae such as *Chlorella* which serve as aeration devices in the lagoons. The algae produced in the sewage oxidation ponds can serve as a source of low cost protein. The aerobic oxidation pond seems to remove 99 percent of coliform organisms and pathogenic bacteria of *Salmonella* and *Shigella* group.

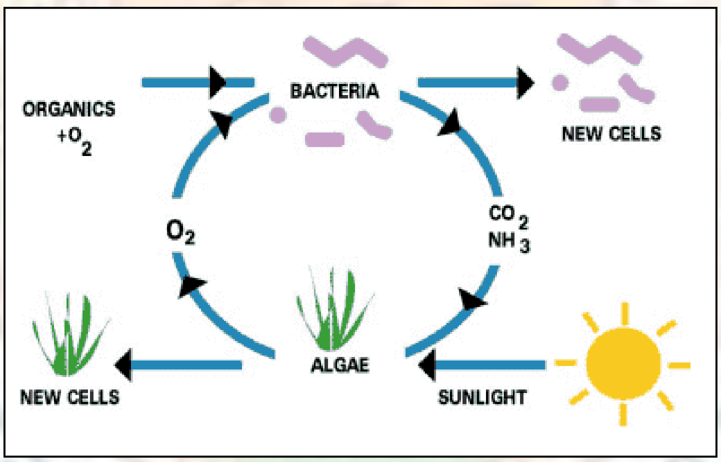


Figure: Symbiotic relationship between bacteria and algae in a sewage treatment

Source:http://www.unep.or.jp/ietc/publications/techpublications/techpub-15/2-4/4-2-3.asp

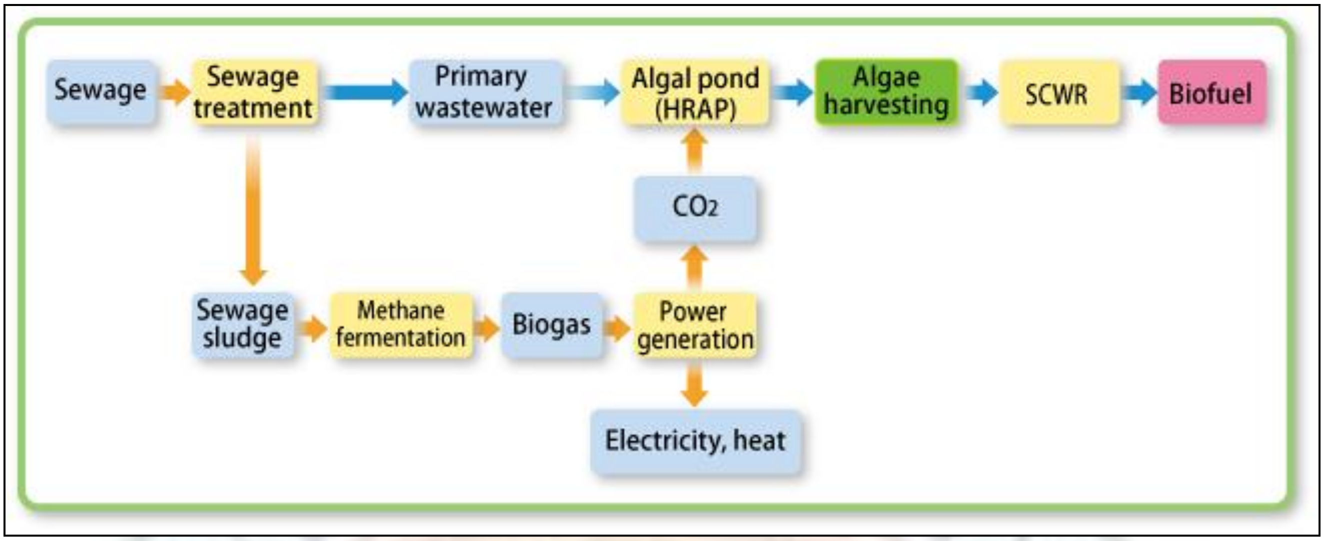


Figure: Biofuel production from algae using **sewage**

Source: http://www.asiabiomass.jp/english/topics/1109_03.html

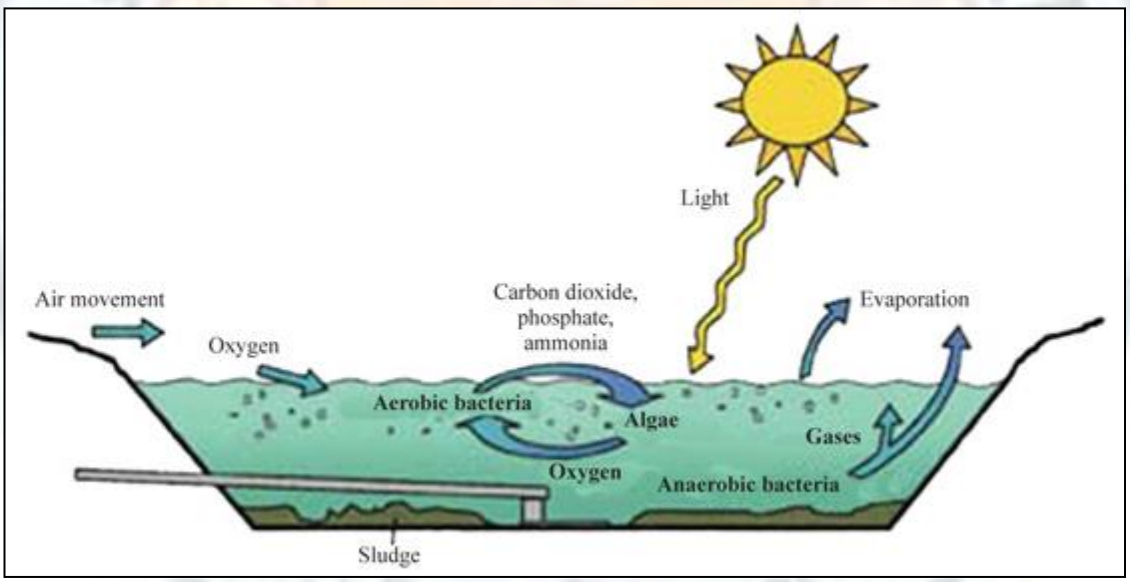


Figure: Aerobic and anaerobic processes in a Sewage lagoon

Source:http://omegamanjournal.wordpress.com/2012/08/22/septic-tank-alternatives-lagoons-and-constructed-wetlands/

The effluent is stable and can be safely discharged into the nearby water bodies. Sludge accumulation is negligible. The advantages of this method of sewage reclamation are:

(i) waste stabilization ponds are economical for small communities,

(ii) a small city can utilize its limited resources to expand water collecting systems rather than pay for the construction of secondary treatment systems

(iii)The reclaimed water can be used for irrigation purposes

(iv)The algal protein is potentially of a valuable importance as cattle and poultry feed

Case Study: In India there are about 558,089 villages and 3020 towns. If the environmental conditions are to improve in these areas, stabilization of sewage by lagooning seems to offer great possibilities. Ganapati and his colleagues examined the controllable and non-controllable factors in the operation of sewage lagoons at Ahmedabad. In the Pirana sewage farms at Ahmedabad the sewage pumped from the Jamalpur and New Suburban Pumping is carried by an open channel to the farm. The sewage is composed of domestic and textile mill wastes. During the course of 7.5 km, a little amount of natural purification amounting to about 60 percent reduction in BOD takes place. During storing, a thick bloom of algae (*Oscillatoria*) develops which purifies the sewage resulting in a very low BOD. The sewage is stored by the municipal authorities in an area of 350 acres, divided into 250 plots of different sizes called 'drying beds'. Sewage is allowed to percolate and to evaporate so that the solids in the sewage are left behind. These are scraped and carted as manure.Using controlled photosynthesis and closed cycle conversion of organic wastes, the organic wastes are fed into controlled photosynthesis pond. The harvested and enriched algae can itself be used as fertilizer. The harvested algae with the supplemental food are fed to animals which in turn produce meat, milk, eggs, wool, hides and other products. All the waste material like urine, manures waste water and meat trimmings are returned to the pond for biological conversion into algae. These sewage stabilization lagoons are also being exploited for fish farming in many countries such as China, Austria, Hungary, Poland and in some parts of India. The fish grown in sewage lagoons do not feed directly on sewage. The organic nutrients such as phosphates, nitrates and potash are used by the photosynthetic algae which form the food of certain fishes. This is called "Pisciculture sewage farming" and is already being carried out in India. Two such ponds are in operation, one at Madurai in Tamil Nadu and another at Kolkata in west Bengal. The Bidyadhari experimental sewage fish farm at Kolkata works on the principal of an oxidation pond. The raw sewage of the Calcutta municipal corporation is allowed to settle in a lagoon for 2-4 days. The water becomes greenish due to a profuse growth of algae.

Figure: Sewage lagoons in a wastewater treatment plant

Source: http://apps.northcowichan.ca/SiteEngine/activepage.aspx?PageID=154

2. Use of algae in capturing fertilizer runoff from farms (Nature's Green Cleaner): The algae systems can capture most of the phosphorus and nitrogen in runoff. Algae can capture and recover about 90 percent of nitrogen and almost 100 percent of phosphorus from a mixture of manure and fresh water and the dried-out algae can then act as slow release fertilizer for farms. The solution offers better management of the cycle of nitrogen and phosphorus nutrients which plants depend on. The system is practicable now. Farmers would have to set up algal turf scrubber (ATS) raceways covered with nylon nettingto serve as a platform for algae to grow upon.

Figure: Air-dried algae from an algal turf scrubber captured most of the nitrogen and phosphorus in the manure

Source:http://www.popsci.com/science/article/2010-05/algae-cleans-manure-runoff-transforming-organic-fertilizer

3. Using algae to reduce CO_2 emissions:

Carbon dioxide and water are the fundamental requirements for algae's growth and in turn oxygen is released as a by-product. Hence algae are a potential means for biological carbon dioxide fixation to reduce greenhouse gas emissions. Work in this field has been under way for several years, especially in Japan. New algal species have been characterized which can grow at low pH, high CO_2 concentrations and in the presence of No and So. Algae Bioreactors are used by some power plants to reduce CO_2 emissions. Released CO_2 can be pumped into a tank or pond, on which the algae feed. The bioreactor can also be installed directly on a smokestack. The main challenge to developing an effective algal CO_2fixation system is the design of very large, low cost photobioreactors. Countries like US, China, South Korea, Canada have invested heavily on technologies to capture carbon with help of algae and produce bio-fuels. The first CO_2 capture for algae biofuel has been built beside a large coal-fired power station in Australia.

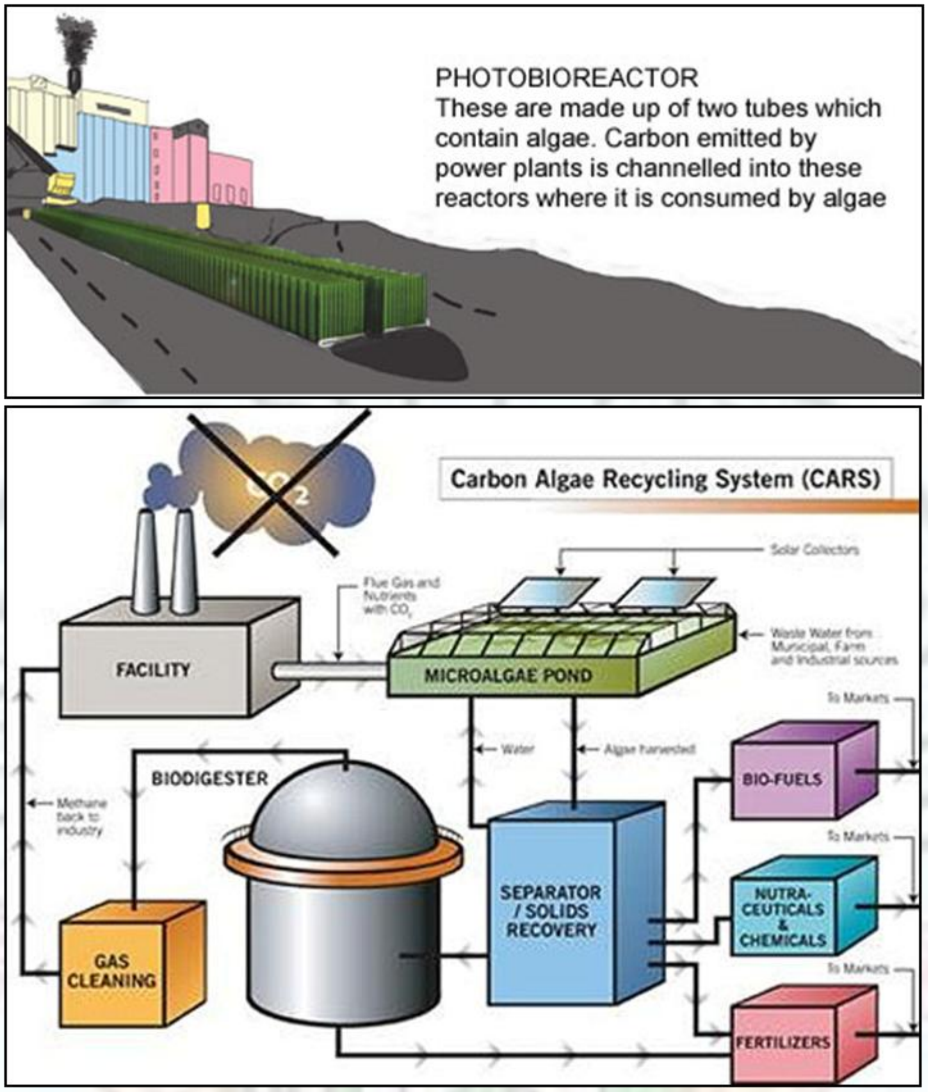


Figure: Algae in reducing industrial CO_2 emissions: Photobioreactors are placed in the vicinity of smokestacks and the emitted carbon is consumed by algae

Source: http://www.downtoearth.org.in/content/carbon-smart

http://goodcleantech.pcmag.com/biofuel/280758-cars-could-produce-earth-cleansing-biofuel-making-algae

Algae has also become a solution for capturing carbon from vehicular emissions, for providing oxygen to solders in high peaks and for reducing oceanic acidification, algae is providing possible answers to increasing carbon emissions across the globe. Professor D.B.Sahoo of Department of Botany, Delhi University has developed algae based carbon neutral car for carbon capturing and reusing the same as bio-fuel. A tank filled with water and algae had been installed on the car. The car's emission pipe was connected to the tank.

The carbon dioxide from the emission pipe was being captured by algae, resulting in less toxic emissions into air. A few algal strains can capture carbon from vehicle's tail pipe and around 40 % of the total fluid generated can be processed into a bio-fuel or other oils for different industries.Algae's versatility has already won over scientists who see it as the biofuel of the future, and the tiny plant organisms have also been proving their worth in scrubbing carbon dioxide and nitrous gas from industrial smokestacks. A company called Algenol has even looked to using **algae-derived plastic** as a replacement for petroleum-derived plastic.

Figure: Algae to reduce car's emissions

Source:http://www.downtoearth.org.in/content/carbon-smart

Algae like *Chlorella* and *Synechococcus* are being used in long distance **space travels** because of their rapid rate of photosynthesis and their ability to utilize all the CO_2 released by astronauts. In turn these algae provide all the oxygen required by them.

4. As indicators of water pollution and environmental assessment:

Algae can function as indicators of water pollution, indicators of environmental change and in environmental assessment. The presence of specific type of algae can indicate the type of a particular environment. For example the lake waters possessing dominant desmid plankton are pure, soft waters. A high organic content of waters is correlated with a dominant flora of blue-green algae. When water bodies are polluted by domestic sewage or organic wastes certain very specific algae such as *Aphanothece, Arthrospira, Oscillatoria, Spirulina, Chlorella pyrenoidosa, Chlamydomonas* etc. come up. The high content of nitrogen generally encourages the algal forms like *Nitzschia, Scenedesmus* and *Merismopedia*.

Therefore algae are an important part of biological monitoring programs meant for evaluating water quality. Algae are suitable for use in water quality assessment due to their nutrient needs, fast reproduction rate, along with very short life cycle. They respond quickly to an extensive range of water conditions. For instance, an increase in the acidity of water because of the acid-forming chemicals which influence lake pH levels, and discharge of heavy metals from industrial areas influence the composition of algal genera that are capable of tolerating these conditions. Water bodies that receive the sources of pollution occasionally, or continuously, display blooms of toxin-producing algal genera. Microscopic analysis of samples collected from water bodies determines the density and diversity of algal species and hence provides helpful early warning signs of the deterioration of water bodies.

The Organic Pollution Index (Palmer Indices)

It is a method to determine the intensity of organic pollution by observing the algae present in a water sample. Pollution index factors of 1 to 5 have been assigned to all the 20 types of algae which are most tolerant to organic pollution. Algae which are most tolerant to organic pollution were assigned a factor of 5. Less tolerant algae were assigned a lower factor number.

Genus	Index	Genus	Index
Anacystis	1	*Micractinium*	1
Ankistrodesmus	2	*Navicula*	3
Chlamydomonas	4	*Nitzschia*	3
Chlorella	3	*Oscillatoria*	5
Closterium	1	*Pandorina*	1
Cyclotella	1	*Phacus*	2
Euglena	5	*Phormidium*	1
Gomphonema	1	*Scenedesmus*	4
Lepocinclis	1	*Stigeoclonium*	2
Melosira	1	*Syndra*	2

Figure: Palmer’s organic pollution indices

Source: Algal genus pollution index (Palmer, 1969)

These values are totaled after analysis. A factor score of 20 or more is considered as confirmation of an elevated level of organic pollution inside the waterbody. Scores ranging from 15-19 point toward probable organic pollution.

Nutrient-related organic pollution significantly impact aquatic life and drinking water quality. Nutrients get into the water bodies through sewage discharges, agricultural and urban runoff, and detergents containing phosphorus. Analysis of the algal flora composition and density in a water body is a valuable tool in the monitoring programs. Palmer indices serve as useful analytical tools for the assessment of eutrophic and non-eutrophic water conditions by grouping algae that are absent or present in various aquatic environments.

Role of algae in agriculture:

(i) As manures and fertilizers: Use of algae as manure in agriculture dates back to very early times. Seaweeds are applied directly or in the form of compost. Now-a-days liquid seaweed fertilizers have come in the market. It has been observed that these fertilizers improve the yield and quality of the crop. Seaweeds are rich in nitrogen and potash but poor in phosphates. Seaweeds are also a valuable source of trace elements and other organic substances like amino acids, gibberellins, auxins and vitamins.

Besides seaweeds, blue green algae are also of utmost manurial importance. The manurial importance of blue green algae depends on their capacity to carry out photosynthesis and nitrogen fixation. The ability to fix nitrogen is of considerable importance in tropical soils, predominantly in the rice fields where these species (*Nostoc, Anabaena, Tolypothrix* etc.) can be used to supplement the inorganic nitrogen fertilizers.

(ii) In the reclamation of alkaline soils: Alkaline soils are considered as waste and useless for cultivation of crop plants. It had been suggested that growth of blue green algae on these soils brings about a remarkable change in the alkaline pH, physical texture and chemical composition of soil. They also increase the water holding capacity of soil and increase its nitrogen, phosphorus and organic matter content. Rapid growth of *Zygogonium* and *Hormidium* reduce soil erosion on disturbed soils.

(iii) Algae as human food: Most common algae used for human consumption are seaweeds. Seaweeds are abundantly used as human food in Japan. Around twenty different kinds of algae belonging to green, brown, red and blue-green algae are eaten by Japanese people. The total sales of *Porphyra* alone in Japan amounts to around 90 million US dollars in a year. Seaweed farming (*Porphyra* and *Laminaria*) in Japan is a major agricultural industry. In the Indian coasts many seaweeds such as *Rhodymenia, Sargassum*, *Enteromorpha* and *ulva* etc. are available but farming and utilization of these natural resources is not as much pronounced. Seaweeds provide a very good supplement for a balanced diet because of their high nutritional qualities and rich mineral content. Other algae which are potentially useful as human food are the unicellular forms like *Chlorella*, *Scenedesmus* and *Spirulina*. The proteins of these algae contain all essential amino acids required for human and animal nutrition.

Biotechnology (genetic engineering) of Algae

Genetic engineering (genetic modification) of algae is the direct manipulation of an alga's genome using biotechnology. New DNA can be inserted in the algal host genome or genes can be removed. There are currently exhaustive global research aimed at increasing the accumulation of lipids, hydrocarbons, alcohols, polysaccharides, and other compounds in algae through genetic engineering. Algae are of considerable interest due to their high photosynthetic conversion efficiencies, metabolic capabilities, higher growth rates, and their ability to store energy-rich hydrocarbons. Around 30 strains of algae have been successfully transformed to date, raising hopeful scenario for creating designer algae which exhibit desired features. Basic steps involved in genetic engineering of algae are:

1. Identifying an organism with a specific attribute
2. Identification and isolation of the gene of interest
3. Cloning the gene, amplifying the gene to produce many copies
4. Manipulate a gene to express by associating the gene with a specific promoter and poly A sequence and insertion into plasmids
5. Multiplying the plasmid in bacteria, recovering the cloned gene construct for injection
6. Transfer of the cloned construct into recipient algal cells
7. Transformation, inserting the gene into the algal cells
8. Culturing of algae

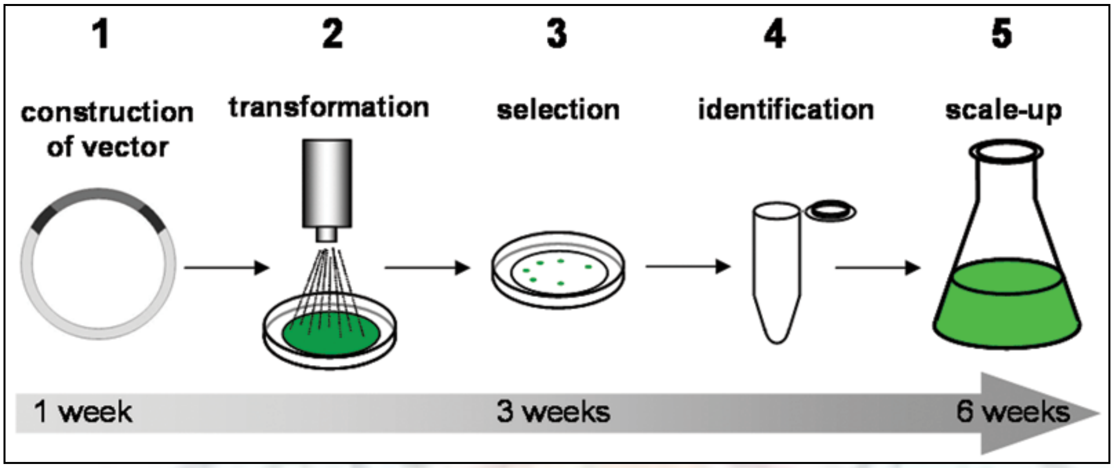


Figure: Genetic engineering of algae

Source: http://www.landesbioscience.com/curie/chapter/4328/

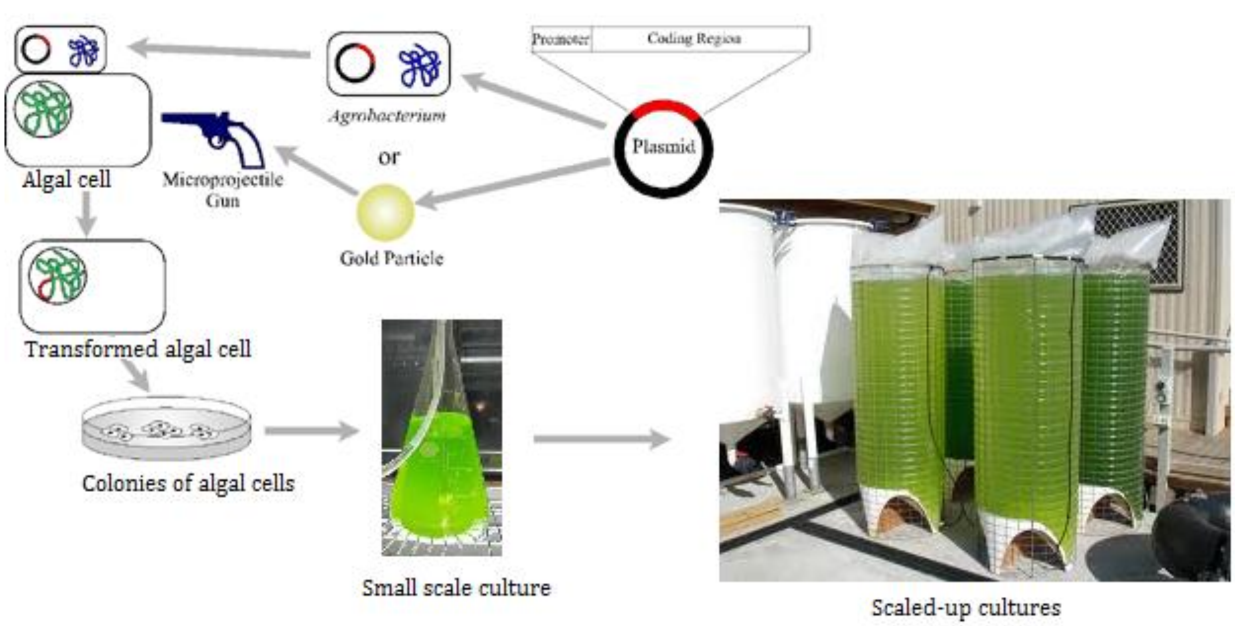


Figure: Transformation and culturing of genetically engineered algae

Source: Author

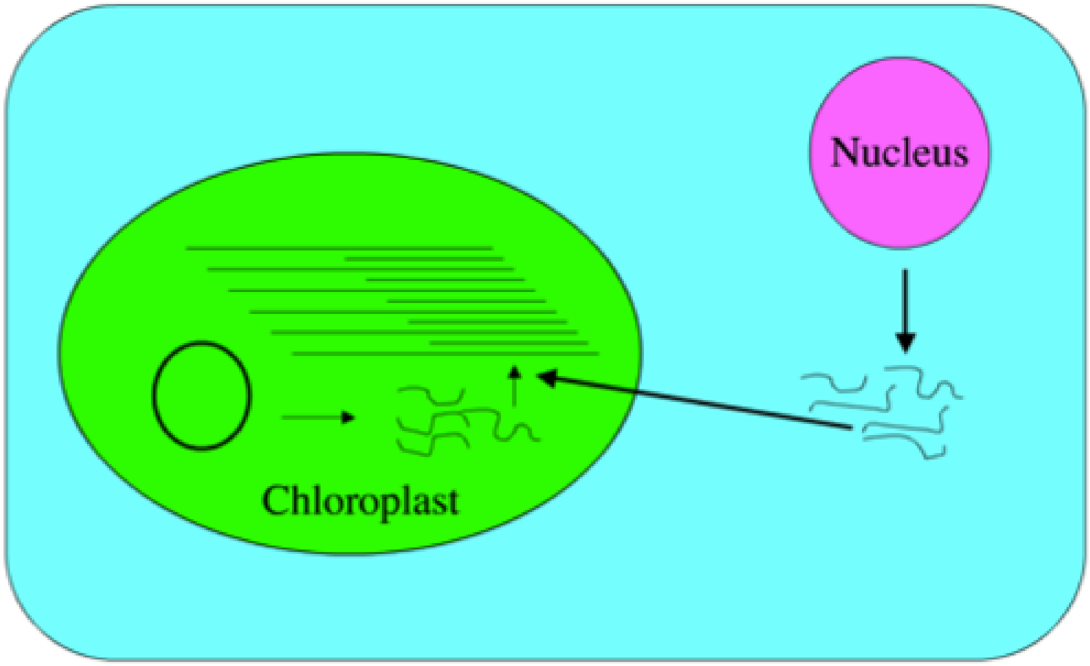


Figure: Biofuels are made in chloroplast from photosynthesis and most of the enzymes involved in biofuel production are encoded by the nucleus.

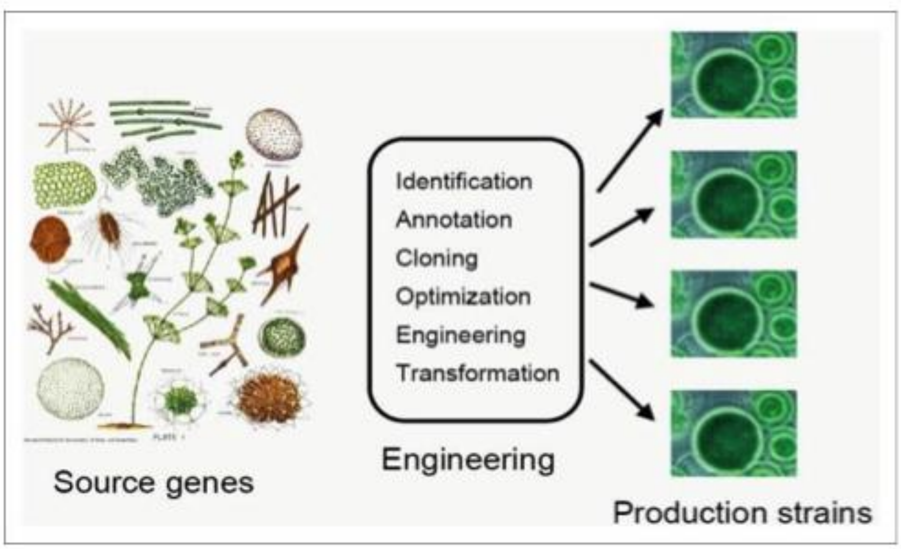


Figure: Genetic engineering of microalgae

Source: http://www.tatup-journal.de/tatup121_ropo12a.php

Genetic engineering of algae: Examples of industrial and environmental applications:

(i) N-fertilizers and Bioremediators

Paddy cultures with the genetically improved cyanobacterial mutants (with mutations in the genes that code for enzymes of the pathway of amonium assimilation) are 40 to 45 percent more efficient in terms of nitrogenase synthesis, as compared to results obtained with the wild type cyanobacteria.

Genetically engineered Cyanobacteria also have numerous advantages in the bioremediation of surface water. Bioremediation by cyanobacteria has lower costs as compared to heterotrophic bacteria, because cyanobacteria do not depend upon external organic carbon source. Cyanobacteria can also degrade target pollutants. Cyanobacteria can combine aerobic and anaerobic degradation, because in the filamentous nitrogen fixating cyanobacteria aerobic metabolism occurs in the vegetative cells whereas anaerobic conditions occur in the heterocysts.

Additional studies of genetic engineering in algae and bioremediation have been carried out on the green alga *Chlamydomonas reinhardtii*. Algae growing in heavy metal contaminated sites evolve different biochemical and physiological strategies to decrease the toxicity. *Chlamydomonas sp*. produce heavy metal binding phytochelatins. *C. reinhardtii* has been genetically engineered by expressing a foreign metallothionein gene to increase its heavy metal binding capacity.

(ii) Genetic modification of algae for Industrial applications:

Hematococcus pluvialis, a green alga naturally accumulates astaxanthin under unfavorable growth conditions. Gene that codes for the enzyme responsible for converting ß-carotene into astaxanthin had already been identified from *Haematococcus pluvialis* and this gene has been cloned into *Synechococcus*. *Synechococcus* converts beta-carotene into zeaxanthin. After this transformation zeaxanthin together with astaxanthin was produced.

The potential of algae for bio-fuel production has accelerated the development of algae-based production systems. Genetic modification (GM) of algae is now being investigated with the aim of increasing the productivity or enhancing the composition of the anticipated products in the GM-algae. Genetic engineering has a very important role in the modification of microalgae for the production of gaseous biofuel (H_2 production). Examples of genetically engineered microalgae used for H_2 production are *Chlorella vulgaris*, *Chlamydomonas reinhardtii* and *Synechocystis.* Algal ethanol and butanol is produced from genetically modified *Synechococcus* and *Synechocystis*. *Synechococcus elongatus* has been genetically engineered to produce butanol, isobutaraldehyde and isobutanol.

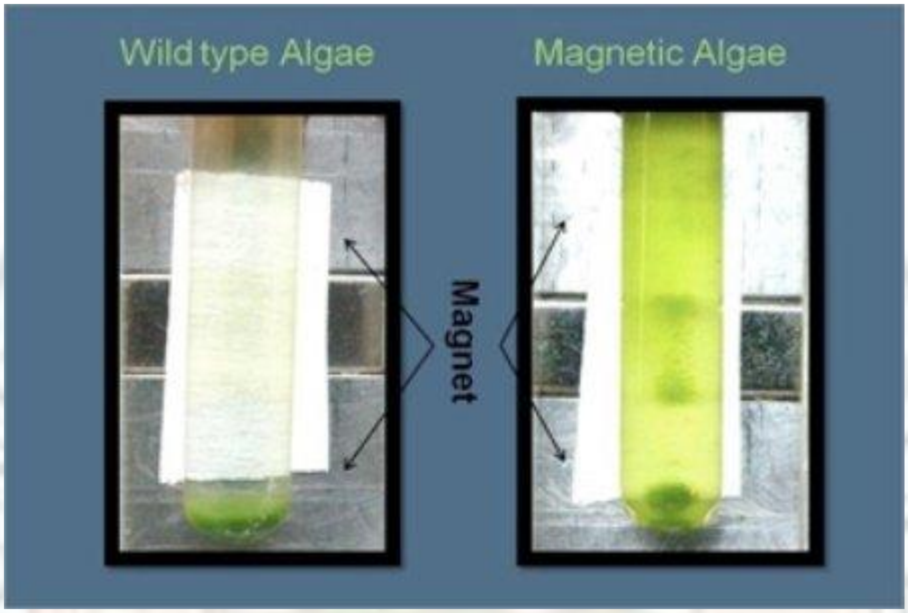


Figure: Genetically modified magnetic algae, magnetic algae stick to side walls and easy to manipulate whereas wild type algae settles on the bottom.

Source: http://www.popsci.com.au/science/energy/genetically-modified-algae-are-magnetic-for-ease-of-manipulation

Job opportunities in algae-based work

Algae-based solutions have created new jobs, new growth opportunities with reduced costs and also helped in rural upliftment. Professor D. B. Sahoo of Department of Botany, Delhi University had worked towards untapping the seaweed resources as a promising source for alternative livelihood in the Orissa (Chilka lake). This work has resulted in the socio-economic upliftment of the fishermen community in different parts of Indian coasts. Department of Science and Technology, Government of India has originated a National project on large scale seaweed cultivation and processing for livelihood generation in different coastal states and Union Territories of India. According to a survey conducted by the algal biomass organization in New Mexico use of algae for clean energy will add 200,000 new jobs in New Mexico.

<iframe width="420" height="315" src="//www.youtube.com/embed/ey2P5hGRjPc" frameborder="0" allowfullscreen></iframe>

Video: Seaweed cultivation and the socio-economic upliftment of the fisherman community in Orissa (Chilika- The untold story)

Source: http://www.youtube.com/watch?v=ey2P5hGRjPc

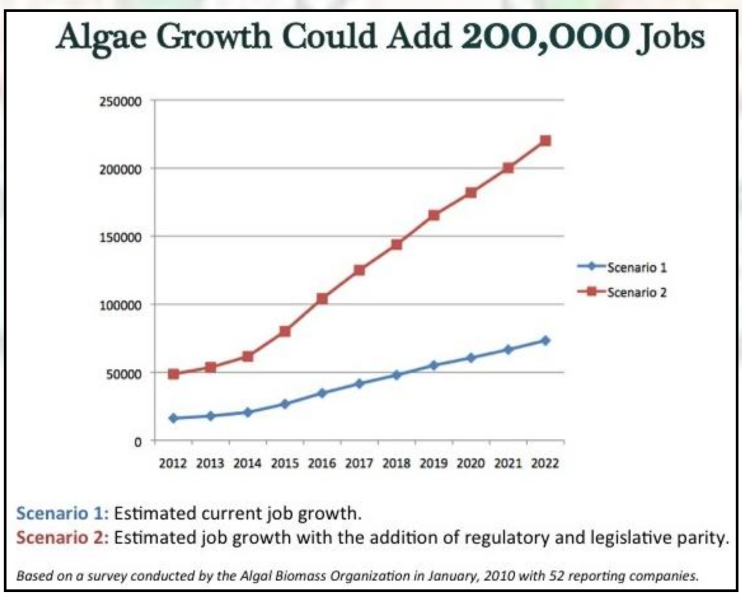


Figure: Estimated job growth in New Mexico by using algae for energy (according to a survey in New Mexico)

Source: http://www.tomudall.senate.gov/?p=blog&id=924

Exercise/ Practice

1. Describe the role of algae in sewage disposal.
2. Describe the role of algae in industry.
3. Write short notes on:
   (i) Algae as indicators of pollution
   (ii) Algae in reclamation of soil
   (iii) Algae as food
   (iv) Algae as fertilisers
   (v) Biofuel production from algae
   (vi) Role of algae in reducing CO_2emissions
   (vii) Genetically engineered algae
4. Fill in the blanks:
   (i) Agar agar is extracted from ……………………….
   (ii)Alginic acid is extracted from……………………….
   (iii) Carrageenan is extracted from…………………….
   (iv)………………is used in research laboratories for the preparation of culture media.

Glossary

Aquaculture: Farming of aquatic organisms for ex. Crustaceans, mollusks, fish and aquatic plants.

Autotroph: not needing an external source of organic compounds as an energy source. Energy is obtained from light or inorganic chemical reactions.

Biofilters: Living material used to capture and biologically degrade or process the pollutants.

Bioremediation: Use of any biological organism's metabolism to remove pollutants.

Carotenogenesis: Increased accumulation of certain carotenoid pigments in algae in response to stress conditions such as nitrogen deprivation, phosphate limitation, desiccation, high CO_2 concentration etc.

Carotenoid: yellow, orange, or red hydrocarbon fat-soluble pigment

Cellulose: polysaccharide composed of -1, 4 linked glucose molecules that forms the main skeletal framework of most algal cell walls.

Environmental indicators: They track the state of a particular environment.

Kelps: Kelps are large seaweeds which belong to brown algae (Phaeophyceae).

Eutrophic water body: A water body rich in nutrients and having an excessive growth of algae and therefore diminished oxygen content to the damage other organisms

Sewage: Sewage comprises of water borne domestic and industrial wastes of the community and contains organic and inorganic parts in dissolved or suspended stage.

Photobioreactor: It is an installation for the production of cyanobacteria, microalgae or macroalgae inside an artificial environment.

Seaweed: Seaweed is a colloquial term for macroscopic, multicellular marine algae. It includes some members of brown, red and green algae.

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