RANDOM NOTES ON ALGAE BIO-ECONOMICS AND SDG GOAL14

Draft for comments, not to be quoted, prepared for the 4th United Nations Oceans
Forum on Trade related aspects of Sustainable development Goal14
UNCTAD_FAO_UNEP
Geneva, April 2022

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Bioeconomy refers to the development, and revitalization of economic systems based on the relationship between economy and biology include the sustainable use of renewable biological resources instead of fossil resources in production process. Biotechnology is a central element of bioeconomy and of bioeconomy policies, for it offers technological solutions to health, natural resources and ecosystem management and sustainability. Besides, through biotechnology it is possible to increase productivity, to develop new products and processes such as biopharmaceuticals, recombinant vaccines and industrial enzymes.

Bioeconomy call for the use biotechnology on a large scale, to make use of biological systems and processes for the production of a variety of products in different sectors:

- Industry – white biotechnology uses enzymes and micro-organisms to make biobased products including chemicals, food and feed, bioenergy and textiles;
- Medicine, (red biotechnology);
- Agriculture: (green biotechnology);
- Aquaculture: (blue biotechnology);
- Pollution removal and bioremediation: (gray biotechnology).

The perspectives of algae bioeconomy are great, from resource-efficient large-scale manufacturing of products such as chemicals, materials, food, pharmaceuticals, polymers, flavors, and fragrances to the production of new biomaterials and bioenergy.
These potentialities are examined in relation to the UNSDGs.

1.- UNSDG 14, CONSERVE AND SUSTAINABLY USE THE OCEANS, SEAS AND MARINE RESOURCES FOR SUSTAINABLE DEVELOPMENT USE.

The 2020 SDG Index highlights that countries are not on track to the achievement of the SDGs. The COVID -19 Pandemic aggravated the already exiting hindrances such as resource scarcity, poor technological dissemination, absence of political will.

The UNSDGb14 deals with the interaction between socio-economic and marine systems. It has 7 targets and three means:

- 14.1. reduce marine pollution
- 14.2. protect and restore ecosystems
- 14.3. reduce ocean acidification
- 14.4. sustainable fishing

- 14.5. conserve coastal and marine areas
- 14.6. end subsidies that contribute to overfishing
- 14.7. increase the economic benefits from sustainable use of marine resources
- 14.a. increase scientific knowledge, research and technology for ocean health Emerging applications of microalgal biotechnology demonstrate the potential for microalgae to solve some of these challenges by reducing aquatic pollutants, as well as providing a source of sustainably produced feedstock for product development.
- 14.b. support small scale fisheries
- 14.c. implement and in force international sea law.

The 17 SDGs are interlinked, meaning that an action in one SDG will affect the outcomes in other SDGs, and that any development must balance social, economic, and environmental sustainability. In other words, the UNSDGs should not be tackled in isolation, rather they have to be considered in their mutual interaction.

The first and second World Ocean Assessments reported the degradation of the marine and coastal habitats, including mangroves, corals and seagrass as well as of open and deep seas affecting the structure and functions of marine systems, thus jeopardizing the potential benefits to be obtained from them.

It is believed that the sound management and use of the great ecological diversity of algae and microalgae including cyanobacteria together with algae-biotechnology can assist in the achievement of a number of SDGs including Zero Hunger, Clean Water and Sanitation, Affordable and Clean Energy, Responsible Consumption and Production, Life Below Water and Life.

The need for an integrated approach to SDGs appears evident when considering the multiple potential uses of algae and biotechnology.

Algae use can contribute to the achievement of target 14.1: reduce marine pollution, 14,2 protect and restore ecosystems, 14.3: reduce ocean acidification, 14.5 conserve coastal and marine areas, 14.7. increase the economic benefits from sustainable use of marine resources and means 14.a. increase scientific knowledge, research and technology for ocean health. Emerging applications of algal biotechnology demonstrate the potential for microalgae to solve some of these challenges by reducing aquatic pollutants, as well as providing a source of sustainably produced feedstock for product development.

2.- ALGAE: DIVERSITY, AVAILABLENESS, CHARACTERISTICS, POTENTIAL USE.

It is not known how many types of algae exist It has e been estimated that algae include anything from 30,000 to more than 1 million species[1]. The algae collection of the US

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[1] Guiry Michael D. 2012How many species of algae are there? J Phycol.48, 1057-1063

National Herbarium consist of nearly 320,500 dry specimens. Another recent estimate suggests 72,500 algal species worldwide.

Most algae are aquatic photosynthetic eukaryotic and autotrophic organisms (they generate internally the food they need) and have chlorophyll as their primary photosynthetic pigment.

Algae are the foundations of the food chain in aquatic environments. They are a food source for many marine organisms including brine shrimps and krill, which in turn serve as the nutrition basis for other marine animals

There are two main group of algae: macroalgae and microalgae.

Macroalgae are large and multicellular aquatic photosynthetic plant-like organisms that are visible to naked eye, and they are **commonly referred to as 'seaweeds**. There are three groups of macroalgae based on their color: red algae, green algae and brown algae. Macroalgae are important in biofuel production and as a food or as feedstock.

Microalgae are small marine, **eukaryotic, unicellular aquatic photosynthetic plant-like organisms**. They are **commonly known as phytoplankton.** There are two main groups of microalgae: **diatoms** and **dinoflagellates**.

Both macroalgae and microalgae produce oxygen, and contribute to food production in aquatic systems, they have the following similarities:

- They are photosynthetic organisms.
- They have photosynthetic pigments as well as accessory pigments.
- Both are potential sources of biofuel production.
- They have nutritional as well as chemical value.
- They are used in different environmental applications such as CO2 mitigation wastewater treatment, biofertilizer production, pigment production, etc.

There are seven major types of algae, each with distinct characteristics:

- ✓ Euglenoidis- Agenous of more than 1,9000 species of single cell flagellated micro-organisms. Lives in fresh and brackish water rich in organic matter
- ✓ Chrysophyta, golden-brown algae and diatoms, are the most abundant types of single celled algae approximately 100,000 different species. Diatoms are useful because they act as a water quality indicator in aquatic environments. Diatoms have been used to study how local environmental conditions have changed as a result of pollution and also to examine long term changes to climate change. They have the ability to convert ammonia to urea that is much less toxic than ammonia. This specie is particularly relevant for SDG 14.
- ✓ Pyrroiphyta, (dinoflagellate= have a cell wall) or Fire algae found both in oceans as well as in fresh waters; they produce light and cause bioluminescence.

However, certain dinoflagellates species can also originate a red tide bloom that can produce toxins that result in the death of marine mammals, fish and birds.

- ✓ Xantthophyta yellow green algae most in fresh water. single cell flagellates yellow green algae are the most common species of algae[2] .
- ✓ Chlorophyta, Green algae, typically live in fresh water; and coastal marine habitats there are 4000 to 7000 species.
- ✓ Rhodophyta, red algae mostly found in tropical marine environments; there are between 5,000 and 6, 000 species.
- ✓ Paiophyta, brown alga**e** are among the largest species including both seaweed and kelp, there are almost 2000 seaweed species.

The first four are microalgae while the other three are macroalgae

To this 7 types some expert also add cyanobacteria**,** known as "blue-green algae", it is a dominant life form on earth they are the only organism group able to transform atmospheric nitrogen into more usable forms like ammonia that can be converted to amino acids and proteins[3]. Yet many authorities exclude all prokaryotes, hence the blue green algae, from the definition of algae

2.1.- Macro-algae, seaweeds

Seaweed farming is the practice of cultivating and harvesting seaweed: In the simplest form it consists of the management of naturally found batches: in its most advanced form it consists of fully controlling the life cycle of the algae. Seaweed grows at a higher rate and do not require fresh water or land space also they do not require industrial fertilizers and pesticides.

Traditional seaweed farming practices have existed for thousands of years. Global production of farmed aquatic plants is overwhelming dominated by seaweeds that increased from 13.5 million tons in 1995 to just over 30 million tons in 2016. And is concentrated in the Asia-Pacific Region.

The global commercial seaweed market size is estimated between US$14.1 billion in 2020 and US$ 16.7 billion in 2020 and is projected to reach US$ 30.2 billion by 2025. Asia Pacific holds the major commercial seaweed market share with a value of US$ 10,73 billion in 2020. World seaweed production is primarily supported by aquaculture: In 1969 the 2,2 million ton of world seaweed production was evenly divided between wild collection and cultivation. However, in 2019 wild collection was still at 1.1. million tons while seaweed cultivation increased to 34,7 million tons, representing 97% of world seaweed production[4]. Seaweed cultivation represent nearly 30% of the 120 million tons of world aquaculture production, while the red and brown algae represent the second and the third largest species group in global

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[2] Bailey Regina 2018. 7 Major Types of Algae. Science, Tech Math>Science Thought Co

[3] Bailey Regina 2018. 7 Major Types of Algae. Science, Tech Math>Science Thought Co

[4] Cai J. Lovatelli S. Stankus, A. & Zhou X. 2021. Seaweed revolution: where is the next milestone? FAO Aquaculture newsletter 63 pp13-26et al 2021

aquaculture only smaller than carps barbels and other cyprinidae[5]. Nevertheless, being low value commodity they accounted for only 5,4% of the US$ 275 billions of world aquaculture production value in 2019.

The largest seaweed producer countries are China, Indonesia South Korea, North Korea, Japan, Malaysia, Zanzibar and Philippines. Some seaweeds are farmed for carrageenan while other for agar. Agar is a gelatinous substance derived from red algae that has a number of commercial uses: it is a good medium on which to grow bacteria and fungi as microorganism cannot digest agar.
Alginates o alginic acid is extracted from brown algae. Its uses range from gelling agents in food, to medical dressing. It has been used in the field of biotechnology as a bio-compatible medium for cell encapsulation and cell immobilization.

Seaweed cultivation is concentrated in a small number of species. In 2019 FAO recorded only 27 different seaweed species cultivated of a total of 443 species in global aquaculture and the 13 060 total selected species in the FAOASFIS (list of species for fishery statistics purposes).

Owing to its functional properties, the red seaweed segment dominates the market and account for the largest revenue share of 52.6% in 2020. It contains a high amount of protein and vitamins that make it a great source of alternative proteins: red algae are primarily used for the production of carrageenan, which itself is used as a food source and has extensive application in food processing. The key benefit of red seaweed is their ability to regulate blood sugar levels and lower bad cholesterol. It is considered a rich source of antioxidants and helps in boosting the immune system and nourishes the skin.
Red seaweeds are extensively used in food. They are used as gelling, stabilizing, emulsifying and thickening in various food products such as ice-creams, jams, fruit juice, bakery products. Over the past few years, the utilization of hydrocolloids such as carrageenan, alginate and agar (the most common macro algae extract) has increased in the food industry, animal feed, pharmaceuticals and other industries leading to an escalation in algae production and soaring demand for commercial seaweed.
Brown algae the second largest macro-algae product segment is expected to increase on account of its growing consumption in Asian Countries. The best know brown algae is the giant kelp. World cultivation of brown seaweeds was 16.4 million tons in 2019 and accounted for 47.3% of world seaweed cultivation in terms of volume and 52% in terms of value and is concentrate in two cold water genera: *laminaria Saccharina* or kelp with 12.3 million tons and *Undaria* known as wakame with 2.6 million tons.   Only four countries China, Rep. Of Korea, North Korea, and Japan produce 99% of brown macroalgae. Cultivated brown seaweed are mostly used as human food (Kombu soup and wakame salads) as well as abalone feed. They are also used as raw materials to produce: 1. Alginate for various food and non-food uses; 2. Animal feed; 3. Biofertilizer or bio-stimulants; 4, pharmaceutical or nutraceutical products and: 5. compostable bio-packing.

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[5] FAO 2021. Top 10 species groups in global aquaculture 2019. World aquaculture performance Indicators (WAPI) Factsheet 4pp

Green algae contain a high amount of beta-carotene which has been shown to be effective in preventing cancer- there is growing demand for dietary supplements in the form of tablets and capsules of green algae.

The increase in the demand for seaweed by the food industry is due its efficiency in adding nutritional value to food products, and the increasing popularity of functional foods.

2.2.- MICROALGAE

Microalgae, including both eutrophic algae and cyanobacteria are photosynthetic organisms that can grow in aqueous media and utilize sunlight to fix carbon into various organic compounds. They normally have a higher photosynthetic efficiency than plants[6] which implies a higher capacity to generate biomass[7] rich in carbohydrates, proteins and lipids.

There are over 200 000 species recognized to date[8], they also show a great range of ecological adaptations since they can be found from the polar regions to hot or geothermal springs, from acids to alkaline environments and from fresh to saline and hypersaline waters: Microalgae naturally thrive in environments with irregular, sporadic and scarce nutrient availability, they grow and can be cultivated in brackish waters. seawaters or wastewaters.

They grow year/round rapidly and have short generation times with average doubling times of 4.8 hour under favorable condition, which can be further optimized through modification of culture conditions[9]. Many algal species are naturally efficient producers of carbohydrates, lipids, proteins, a broad range pigments, as well as a range of commercial secondary metabolites that are recognized for their value in novel product production and biotechnology applications. Secondary metabolites are thought to be play a role in predator defense, protection against infections by various microorganisms, sexual communication and competitor exclusion. Secondary metabolites are structurally complex molecules, which are difficult, or even impossible to produce by chemical synthesis.

Many microalgal species can be cultivated and can be used in many different areas, as a next-generation of bio-factories[10] for the production of: raw materials, biofuels such as biodiesel, bioethanol, and biogas, of valuable chemical substances used in pharmaceutical, nutraceutical, and cosmetic industries, finally thanks to its high protein content they can be used for food and feed.
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Microalgae can be produced in:

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[6] Bhola et al.2014
[7] Benedetti et al 2018
[8] Guiry 2012
[9] Smetacek 1§999 ; litchman 20076
[10] Rasal and Mayfield 2015, VAVITSAS ET AL. 2013.

- Open systems, open ponds or
- Closed systems or photo-bioreactors

Investments and operating costs of closed systems are higher than those of open systems. However, having in mind the manufacture of special products such as nutraceuticals and pharmaceuticals as well as of productivity, closed systems are preferable than open systems.

When grown at large scale – in either a pond or a photobioreactor – microalgae are more water-efficient than crop plants[11] and, many geographical areas could be effectively used for large-scale algal cultivation. Algal biotechnological production is a promising biotechnological area because of high photosynthesis efficiency, and low area requirement for cultivation. In addition, algae can utilize industrial CO_2 emissions directly as a carbon source]. In recent life cycle analysis studies on algae systems show that that CO_2 emissions are effectively reduced in comparison of other production facilities]. Algae can recycle pollutant nitrogen in wastewater.

Each algae species has different mechanism for adapting the cultivation medium and cultivation system and can show different growth patterns. The choice of microalgae species and production conditions should be determined according to the desired products.

Biological, non-biological and operating parameters should be considered for the production of micro-algae. Biological factors include pathogens such as virus and bacteria, and other algae species, Non-biological factors includes light, temperature, pH, salinity and nutrient.

Potential use of macroalgae and microalgae.

1.- Supply of protein for human consumption. Algae are national foods o f many nations: China consumes more than 70 species, including *fat choy*, a cyanobacterium considered a vegetable; Japan, over 20 species such as *nori* and *aonori*, Ireland, dulse; Chile, cochayuyo and rimurapa (durvilaea antarctica), Laver is used to make laver bread in Wales, where it is known as *bara lawr*; in Korea, *gim*. It is also used along the west coast of North America from California to British Columbia, in Hawaii and by the Māori of New Zealand. Sea lettuce and as dabberlocks or badderlocks, or winged kelp (*Alaria esculenta)* are salad ingredients in Scotland, Ireland, Greenland is an edible seaweed, also known, and Iceland. Algae is being considered a potential contribution for the solution for world hunger which is UNDGSDG 2.

Microalgae have long been recognised for their nutritional properties and are considered to be a rich source of protein, with some species having a protein content of up to 50% of dry biomass[12]. Screened, microalgal-derived protein contains all of the essential amino acids required in the human diet, it is a complete protein[11]- Microalgae have been used as human nutritional supplements over decades, now they are increasingly being utilised as bulk ingredients in manufactured foods, such as snacks, pastas, noodles and cereals, to increase both protein content, and t the

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[11] Gorissen et al., 2018; Torres-Tiji et al., 2020

overall nutritional benefits[12]. Two microalgae: the *cyanobacterium, Arthrospira platensis* (spirulina) and the green alga, *Chlorella vulgaris (chlorella*) are currently used as a protein additive in human food manufacturing[15]. More recently, microalgae have been used as a non-animal source of protein for food processing[13] or to replace soy protein. The microalgal protein market is driven mainly by consumer demand for both alternative and sustainable protein sources.

2.- To combat micronutrient malnutrition and associated diseases caused by a dietary deficiency of vitamins or minerals. Microalgae area valuable source of lipids, fatty acids, vitamins and minerals. Cultivated microalgae, including both algae and cyanobacteria, are marketed as nutritional supplements, such as spirulina, chlorella and the vitamin-C supplement from *Dunaliella*, high in beta-carotene. They provide many vitamins including: A, B_1, B_2, B_6, and C, and are rich in iodine, potassium, iron, magnesium, and calcium. Thus, they have been considered by public health and disease control measures to prevent and control malnutrition and dietary improvement. This is also relevant to UNDSG 2.

3- As feed source in aquaculture and agriculture.
Microalgae are used as a food source and feed supplement in aquaculture[17] as an alternative to traditional feedstocks, such as fishmeal. Besides the use of microalgae feed in shellfish aquaculture provides a more sustainable source of seafood than using fishmeal and protect the marine environment from the pollution generated by fish farms by reusing the wastewater generated as a nutrient source for microalgal growth[18]. Nearly 20 algae species have been identified as a suitable live feed for aquaculture [14]. Microalgae are also increasingly used in agriculture as feed for ruminants, pigs and poultry.

4.-. High value products
Only a minute fraction of all algae species is currently profiled from their biochemical capabilities Most high value products that are currently sourced from higher plants are naturally produced or could be produced by algae through genetic engineering and synthetic biology. Microalgae can be genetically engineered to synthesize a myriad of high value products such as metabolites with applications as cosmetic, biofuels, nutraceuticals and pharmaceuticals. To extract these compounds directly from plants require very large quantities of biomass with high economic costs. Microalgae engineered can produce these chemicals in higher concentration than is possible in wild pants.
Other product from engineered algae strains are industrial recombinant enzymes[15] and protein-based therapeutics[16]. Recombinant protein drugs are today produced in microbes as E-Coli, yeasts or mammalian cell lines with high cost of production. The use of algae has also the advantage of being immune to most pathogens and contamination that affects animal hosts. Some algae have been demonstrate to

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[12] Demirbas 2009
[13] , (Grahl et al.,8, 2020
[14] Laing 1987
[15] Rasala et Al 2012
[16] Rasala et al 2010 ; Gimpel et al. 2015

produce functional therapeutics as human antibodies, immunoglobulin [17] vaccine sub units[18], vaccine antigens [19] , immuno-conjugated cytoxins for cancer treatments,[20] and antibodies [21].

5.- Pollution control and Bioremediation

This use of microalgae is particularly relevant for SDG-14 Life Below Water. Microalgae are recognized natural systems for remediation of diffuse pollution through nutrient assimilation into filamentous algae biomass growing on artificial flow-ways. Sewage can be treated with algae, reducing the use of large amounts of toxic chemicals that would otherwise be needed. Algae can be used to capture fertilizers in agriculture runoff, the enriched algae when harvested, can be used as fertilizer. Research demonstrated that 60–90% of nitrogen runoff and 70–100% of phosphorus runoff can be captured using a algae scrubber, called algal turf scrubber. Wastewater treatment, using microalgae for nutrient removal, is a well established technology that has lower capital and operational costs and is more efficient than traditional wastewater treatment systems.

Besides the increasing presence in the environment of synthetic organic chemicals such as pharmaceuticals, herbicides, pesticides etc. now known as emerging contaminants, are of concern for their potential risk to human health. Microalgae biodegradation appears as a promising technology to transform, neutralize or eliminate emerging contaminants from agricultural runoff. The large number of enzymes present in microalgae permit the degradation of a range of organic compounds, in other words: microalgal degradation of emerging contaminants relies on a complex enzymatic process involving a number of enzymes. However, the large number -thousands- of recognized algae species, associated with the also large number of emerging contaminants, nearly 200 known, require a laborious double screening of a wide range of microalgal species against a wide range of emerging contaminants. It is considered that a cost effective high through-put screening method allowing rapid screening can be developed by a microalgae phenomic facility and the improved efficiency through the application of genetic engineering, synthetic biology and targeted gene editing.

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[17]

[18] Gregory et al 2013

[19] Demurtas et al 2013

[20] Tran et al. 2013

[21] Barrera et al 2015

6 -Bioipolymers bioplastics and bulk chemicals.

Various polymers can be created from algae, which can be used in the creation of bioplastics, including: hybrid plastics, cellulose-based plastics, poly-lactic acid, and bio-polyethylene. The increasing worldwide generation of non-biodegradable petrochemically based plastics-wastes is matter of concern. Algae is considered as an economic viable feedstock alternative to bioplastic production. There are three main approaches to produce bioplastic from microalgae: a) direct use of microalgae as plastics, b) blending of microalgae with petrochemical-based plastics and, c) genetic engineering of microalgae to produce bioplastic polymer.

In addition to microalgae, also the use macroalgae - green, red and brown algae biomass- has been recently considered for the production of acid plastics[22]. Biomass-derived chemicals such as: sugar alcohols, lactic acid, phenols are considered to be used for the production of a great variety of chemicals in industrial scale. Microalgae with its superior productivity to traditional agricultural crops and high concentration of lipid, carbohydrate, and proteins have appeared as an alternative for the production of bulk chemicals and biobased solvents[23].

7.- Bio-fuels: biodiesels, bioethanol, biobutanol

The rich carbon contents and high growth rates of microalgae makes them an interesting renewable feedstock for biofuel as an alternative to traditional methods. A variety of prokaryotic (cyanobacteria) and eukaryotic microalgae have been identified as promising candidate hosts for the production of biofuel. Besides, they have a high CO2 fixation capacity by photosynthesis and high biomass and lipid productivities. Other microalgae's advantages are low water and land requirements. Genome editing could further increase their photosynthetic and productivity potential.

Distinctive properties of algae are:
1.- CO2 absorbance for the growth, it can utilize industrial CO2 emissions directly as carbon source[1]. So, helps out in reduction of green-house effect;
2.-high photosynthesis efficiency;
3.- they do not require large area for development compared with other food crops;
4.- can adjust to brine water;
5.- The high lipid content. enables its successful conversion into biofuel;
6- High content of carbohydrates which is a feasible feedstock for bioethanol;
7.- very high rate of growth (doubling by 24h);

The lipids in algae can be converted to biodiesel by generalized method used for the conversion of vegetable oil into biodiesel, Bioethanol and biobutanol are prepared from the carbohydrates of algae particularly *Chlorella vulgaris*, a microalgae

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[22] Bulota and Budtova 2014

[23] Wijffels et al 2010

frequently used in industry because its high productivity, high lipid content, high rate of CO2 fixation, and high tolerance to environmental conditions.

The biofuel production from algae proceeds through the following steps:

1.- culturing of algae
2.- harvesting of algae – and dewatering of algae
3.- extraction of oil from algae
4.- purification of algal oil
5. processing of oil into biofuels.

Algae can be produced in: i) open pond systems, is the most common system used in the algal growth. There are different types: raceway ponds, natural ponds, circular open ponds etc. ii). a second method is to use photobioreactors or closed reactor systems- This has a high capital cost, and iii) the third option is the hybrid systems or phototrophic system the advantage is that the algae grow using CO2 and sunlight so it is economical, yet a slow rate of growth is observed.

Bioethanol and biodiesel obtained from agricultural sources have lower global warming potentials beside they compete with agriculture and food production for land. Besides the algal oil is inedible so do not interfere whit food availability.

3.- ALGAE potential use for the achievement SDG14: Life Below Water

Targets

- 14.1. reduce marine pollution
- 14.2. protect and restore ecosystems
- 14.3. reduce ocean acidification
- 14.4. sustainable fishing
- 14.5. conserve coastal and marine areas
- 14.6. end subsidies contribution to overfishing
- 14.7. increase the economic benefits from sustainable use of marine resources
- 14.a. increase scientific knowledge, research and technology for ocean health

Target 14.1 states that “to prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. This implies that freshwater should be explicitly considered since most of marine nutrient pollution particularly nitrogen and phosphorus comes from point and diffuse sources such as agricultural runoff, and discharged in oceans by land based waterway impacting estuarine and coastal marine ecosystems. This target is related to SDG-2, SDG-10, SDG-11, SDG-12 and SDG-13.

Most of marine pollution, ocean acidification, coast and marine ecosystem deterioration originate in land. Diffuse pollution, such as agricultural runoff and storm-water, has been identified as a major source of nutrient input, in particular nitrogen and phosphorus, into aquatic ecosystems. Emerging applications of microalgal biotechnology has the potential to solve some of these problems by reducing aquatic pollutants, and at the same times providing feedstock for product development.

The use of microalgae to bioremediate a wide range of polluted and nutrient enriched wastewaters through paddlewheel-mixed High Rate Algal Ponds (HRAP) has been demonstrated to be cost effective and efficient compared to conventional wastewater treatment ponds[24]. HRAPs are shallow, paddlewheel-mixed, that enable the circulation and flow of suspended algae in open ponds enhancing both the growth of free-floating microalgae and their nutrient assimilation, allowing a high removal of nutrient compared to conventional wastewater ponds. In HRAPs treating municipal wastewater the removal rates for ammonium-nitrogen range from 50-75%, while the rates for phosphorus removal range from 5- 50%[25], compared, with removal rates from 10-20% for ammonium nitrogen and 10–25% for total phosphorus in conventional wastewater treatment ponds range[26] . The capital and operational costs of HRAPs are estimated to be only 25–33% of those of secondary-level activated sludge treatment[27]. Despite the lower cost to date only two full-scale HRAPs wastewater treatment have been built, both in New Zealand. These full-scale systems successfully demonstrated high microalgal productivity and wastewater treatment[28].

As with free-floating microalgae also filamentous algae can rapidly assimilate nitrogen and phosphorous from the water into its biomass. By growing filamentous microalgae on an artificial stream, or flow-way, water can be diverted onto the flow-way while the microalgae assimilate the nutrients from the water.To cultivate filamentous algae provides a biological treatment system for diffuse nutrient pollution in both fresh and coastal marine waterbodies were algae assimilate the nutrients from the water. Filamentous algae treatment systems have been considered as potential cost-effective mitigation technologies for diffuse nutrient pollution, including algal turf scrubbers and filamentous algae nutrient scrubbers.

It has been demonstrated that the average total nitrogen removal rates by filamentous algae were more than double that of conventional constructed treatment systems, and that total phosphorous removal rates were more than four times that of conventional waste-water treatment. Conventional wastewater treatment do not permit nutrient recovery which means that tons of valuable nutrients are lost with negative impact on the environment, while the filamentous algae remove nutrient by assimilation which means that the algal biomass can be recovered for use as

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[24] Craggs et al., 2015

[25] Rawat et al., 2011; Craggs et al., 2012; Sutherland et al., 2018

[26] Nurdogan and Oswald, 1995; Craggs et al., 2003; Borowitzka and Moheimani, 2013).

[27] Green et al., 1995; Downing et al., 2002).

[28] Craggs et al., 2012, Craggs et al., 2014 and Sutherland et al., 2014, Sutherland et al., 2018.

feedstock for new products[29], therefore it also contribute to the achievement of SDG7 and SDG-12, as well as SDG-13.

Besides the lower nutrient removal rate the traditional treatment have other disadvantages over filamentous microalgae flow-ways, such as higher construction costs per unit land area and lower treatment capacity[30], that are not economically feasible in low income countries and particularly in rural areas.

Filamentous algae flow-ways have also been used to remediate diffuse nutrient pollution associated with aquaculture facilities, including oyster, catfish, and shrimp farms [31].
In this perspective the achievement of SDG14 targets 1; 2; 3 and 5 are linked to SDG6 clean water and sanitation, particularly targets 6.3, 6.4.and 6.6 related to improvement of water quality, wastewater treatment and safe reuse and increase water-use efficiency and supply.

In addition to nutrient and pathogen pollution, the presence of emerging contaminants in aquatic systems and their associated risks to human health have negative implications for SDG-6. Emerging contaminants are primarily synthetic organic compounds that fall into several broad categories including pharmaceuticals, personal care products, illicit drugs pesticides. Conventional wastewater treatment plant are not designed to treat and remove emerging contaminants that enter waterways via human-mediated routes. Microalgae can bioremediate emerging contaminants s via three main pathways; bioadsorption, bio-uptake and biodegradation. Both bioadsorption and bio-uptake processes concentrate and remove emerging contaminantss from the wastewater for more efficient management and disposal In contrast, microalgal biodegradation involves the transformation of the contaminant into simpler, less toxic compounds, effectively neutralising, or eliminating the emerging contaminants. This appears as a most promising technologies for the remediation of emerging contaminants from water sources[32]. It has been reported that over 30 pharmaceuticals and personal care products including, synthetic hormones and antibiotics have been biodegraded by microalgae[33]: 59% biodegradation of the hormone progesterone has been demonstrated by two freshwater microalgae, *Scenedesmus obliquus* and *Chlorella pyrenoidosa*[34], and 100% biodegradation of the antibiotic Ciprofloxacin[35],[36].

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[29] Sutherland and Craggs, 2017

[30] ; Pizarro et al., 2006

[31] Valeta and Verdegem, 2009; Ray et al., 2015a, Ray et al., 2015b; Mitchell, 2018

[32] Sutherland and Ralph, 2019 (Sutherland and Ralph, 2019

[33] Norvill et al., 2016; Sutherland and Ralph, 2019

[34] Peng et al., 2014

[35] Bai and Acharya (2016)

[36] Xiong et al. (2017)

Microalgal-based wastewater treatment coupled with bioremediation of emerging contaminants offers a potential cost-effective remediation solution that will contribute to achieving SDG-6, while the improved effluent water quality will lead to improved environmental outcomes in the receiving environment thus contributing to SDG-14 and SDG-15 and reduce the negative impacts of urban agglomerations, which contribute to the achievement of SDG-11 Sustainable Cities and Communities.

4. Technology and Biotechnology for algae utilization

Technology and technological innovation are fundamental for achieving SDG in this context microalgal biotechnology should be considered. Biotechnology requires the deeper understanding of algae biology genetics and biochemical capabilities
The production of algae for any end product implies a two-phase process: a) the farming and cultivation of algae biomass, and, b) the processing of the harvested biomass for the final desires product such as food, food additive, feed, bioplastic o biofuel. Biotechnologies are need to increase productivity I in the algae cultivation and in the process of transformation of biomass, Besides biotechnologies can also be used for the identification of their potential uses and their potential optimization.

Algae bio-economics can be advanced by the increasing application of phenomics, synthetic and molecular biology, genome sequencing and mapping and nanotechnologies particularly nano-materials.
Algal biotechnology is still very young, very few algae species have characterized, and most algae strain are relatively uncharacterized and yet strain selection is key to optimize productivity through genetic engineering or synthetic biology.

The objectives are to maximize productivity and increase the economic potential of algae, the following biotechnologies are envisaged**:**

1. Phenomics: refers to the acquisition of phenotypic data in an organism-wide scale: In the algae domain phenomics is in a very early stages of development. The problem is the lack of researchable phenomics database Hence the need to build a comprehensive phenotypic database.
2. Synthetic and molecular biology applies engineering principle to the rational design of living organisms. A system is viewed as a collection of characterized genetic parts that can be modified and reassembled to alter existing functions or to build a new organisms Synthetic biology can create novel, new to nature compounds with potential new functions and applications. Genetic engineering of microalgae is evolving.
3. Genomic sequencing techniques data facilitate the identification of native genetic elements necessary for genetic engineering and successful transformation.
4. Gene editing techniques such as CRISPR-cas9 are increasingly used to create large genome wide libraries of important microalgal species and mapping genotypes.

5. Nano technologies has been used on biofuel conversion to enhance conversion process and engine performance. For these purposes nantechnology draw upon the utilization of nano-additives such as nano-magnet, nano-crystals, nano-fibres etc. Nano additives enhance microalgae cultivation, permit the identification of the most suitable microalgae species for possible biofuels, improve microalgae-biofuel yield, enhance the complete and cleaner combustion in fuel engines by nano-emulsion and nano-additives[37],[38],[39].

5.- Algae International trade

In 2020 the international trade on algae and derivates was USS11.5 millions, representing less than 0.01% of word trade[40].

International trade of algae is restricted to seaweeds and three seaweeds derivates hydrocolloids: agar, carrageenan and alginate. In 2019 algae (sea weeds) exports was US$ 909 million being the Rep. of Korea the main exporter with 30,55% of the total followed by Indonesia, 24.1%, Chile, 9.43 %, China 6.03% and Philippines 4.23%. [41]

The world export of seaweeds derivates hydrocolloids -agar, carrageenan and alginate-, in 2019 was US$ 1,743 million being China the largest exporter with 30% share followed by Philippines with 12.28%, Spain 7,9% and Chile 7.06%.

To sum up, the world total exports of algae (seaweeds) and derivates were US$ 2.652.million The share of China was 21.8% followed by Indonesia with 12.9%, the Republic of Korea, 12.8&, Philippines 9.52% Chile 7,87%.

World import of seaweeds and seaweed-based hydrocolloids was in 2019, US$ 2.9 billion of which USD 1.26 billion of seaweeds and USD 1.74 billion seaweed-based hydrocolloids. The main importers are China, Japan, the USA, and Germany. While China, and Japan are the main importer of seaweeds, the USA, Germany and China are the main importers of Seaweeds derivates hydrocolloids

6.- Barriers and challenges to micro-algal bioeconomy

1.- Despite microalgae's potential as novel protein, polyunsaturated fats sources, health supplements and nutraceuticals, currently, only six microalgal taxa are

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recognised as being safe for human consumption by the primary markets for algae food products. Besides:

- they are not recognised as a food;
- They are often perceived negatively due to their association with algal bloomsand water fouling[42].

- little or no guidance for approving "novel foods" [43]

2.- high cost of seaweed cultivation, particularly harvesting, impede market growth

3.- Dewatering is one of the major expenses in algal processing representing between 20 -30% of total cost

.

4.- Challenges should be addressed in terms of low productivity yield and relatively high cost when considered alone for a single use. The integration in a multipleproduct biorefinery could improve the overall economic feasibility production of: food, high value products, bulk chemicals, and bioplastic production from microalgae biomass: algae biorefineries will allow co-sourcing different products, minimizing waste and maximizing the productivity.[44],[45],[46],[47].

5.- At present biofuels that have received most attention, are not price competitive by comparation with the production costs with those of producing fuel from fossil fuels.

6.- . Most research and studies have been conducted under controlled laboratory conditions or on pilot plants. Therefore, further research is needed under outdoor, pilot-scale condition to better determine algal-bioeconomic costs, efficiency and effectiveness.

7.- The legislation regulating the use of microalgae beyond the current accepted species, and applications is difficult to navigate.

8.- lack a clear authority for regulating microalgae exploitation, cultivation and use[48]

9.- Absence of state or governmental programme or policies concerning algaes.

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[48] Trentacoste et al., 2015. The place of algae in agricultural policies for algal biomass production. Photosynthesis research 2015 Springer

10.- laws clarifying the authority and process responsible for microalgae applications are needed to support the adoption of more algae and microalgae species for product food. micr neutocels, pharmaceutical, bulk chemicals etc sources,

11.- Absence of institutional framework policies to promote the development of bioalgal bioeconomics.