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Microalgae based hybrid approach for bioenergy generation and bioremediation: a review

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ABSTRACT

Bioenergy generation needsanew approach in which a third generation biofuel derived from microalgae. Resources depleting frequently the renewable source must be adapted to get rid of such major issue. Fuel scarcity the population explosion is tie back to back. Anthropogenic activities the main cause of pollution. Awareness towards environment cleaning is our priority. Resources from fossil fuel depleted researchers better switch over to renewable supply. Energy demands for new technology increased by approximately 50% till 2030. A carbon-neutral and a renewable energy supply liquid fuels are needed to reduce the petroleum-derived fuels that contribute to global warming. Microalgae, an aquatic family member, eukaryotic, photosynthetic and microscopic, freely suspended in water. An integrated approach, to bioremediate and also the fast energy generation which is attracting interest for researchers in this era of high fuel demands. Biofuels are produced by different sources but certain limitations as economic or low yield. The microalgae areunique third generation fuel and the byproducts Biodiesel as a transport fuel. Certain natural products, antibiotics, manure, fertilizers, and food feed for animals. Review article draw discusses mainly a- algae culture, b- wastewater treatment processes, c- greenhouse gases or flue gas sequestration, d- nutrients required in growth, e-biomass production of biodiesel, f- Beneficial byproducts.

Keywords: *Microalgae; Bioremediation; Wastewater; Bioreactor ;Biofuel .*

1. INTRODUCTION

Energy crisis and population explosion is an issue which skyrocketed increase. So, an efficient solution should be found immediately. Many Scientists, work to solve the problem because by the year 2030 the energy demand just increases 50%as reported by IEA, (International Energy Agency) (Christi, 2007). Critical point to consider as fossil fuel depleting is geopolitical conflict, weather change, and atmospheric CO_2 concentration increases. Natural energy source, so that the environment is clean and energy demands also achieve. Natural supply as solar, hydro, thermal, wind energy can implement a lot of demands. In this potential energy, sources biofuels can work as a natural supply and the scarcity of fossil fuels is also considered (UNEP, 2009). Anthroprogenic activities lead to a huge amount of green house gases or flue gases, fossil fuel consumption increases, electricity and thermal energy generation are removed by applying certain mitigation strategies so a natural process is adapted to solve such global issues (Ugarte et al ., 2003).

Biofuel a renewable form is produced by biomass and more efficiently. Commencement of biofuels is from animal fats, plant fats, starch, waste biomass and algal biomass. Various categories of biofuels as 1st, 2nd, 3rd and 4th generation are assigned based on the feedstock obtained and their types (Popp et al.,2014, Kumar et al 2017,2018a).

The biofuel industries recently got interested as the demands of resources increases by time. Sources of biofuel also appreciating as it is obtained from non feedstocks such as agricultural wastes, microalgae, certain microbial supply are taken into consideration and the human food chain is not disturb. By using biosources the sudden degradation is found in CO_2 emissions (Halent et al., 2007).

Algae, is a photosynthetic eukaryotic family member, it is found in single and multi-cellular forms in an aquatic medium. Microscopic algae or microalgae exists in water and follow the same photosynthetic phenomena as the plants do (Kumar 2019a). These eukaryotes absorb sunlight and directly convert CO_2 into raw materials which can be used as biofuels, animal feedstock and valuable bioactive products. Microalgae are acquiescent to genetic engineering, biotechnology regarding mass culture in biomass production and carbon sequestration. To obtain biofuel from microalgae is an inspiring and more focusing as it acts as biorefinery (Christi, 2007). The production of natural products from microalgae draws all the attention in the last decades, remediation ability and work as energy potential crop. Without affecting the food over fuel fight microalgae show a combination of easy energy sources. Bioremediation of effluents or wastewaters and various food products that have a high nutritious value produced by microalgae that's why its industrial cultivation is increased (Pienkos et al.,2009) (Table 1,2). Biofuel produced by microalgae has high potential because of low input and high yield results which is a renewable energy application (Kumar et al., 2018b).

2. SELECTION OF MICROALGAL STAIN

Microalgae show different features and their selection to get high biofuel yield. A common and profitable points to be considered are ; (1) Algae could be 6-12 times more efficiently convert solar energy than that of any terrestrial plants ; (2) their end-products are manipulated through control on chemical composition; (3) their metabolic and diversity features allows selection of stains on the bases of morphological features (Hu et al., 2010, Kumar et al., 2019 b). Edwards et al.2010 found that the selection of algal strains depends on the following properties which include growth and efficiency, its harvesting process, lipid yield high and constant plus makes minimal fouling (Table 1).

Chlorella *(protothecoides, vulgaris), Ettlia oleoabundans, Scenedes musobliquus, Naviculas aprophila* all having nearly 55% of lipid content as reported (satyanarayana et al., 2011;Gouveia et al., 2009). The better economic performance achieved in microalgae by manipulating their metabolic activity as increased growth rate, oil content high and process of harvesting became easy (Harun et al., 2010). In studies, it is found microalgae can produce lipid content, carbohydrate and proteins are different depend on particular species. Microalgae, act as a suitable feedstock for producing a bulk of natural oil. Triacylglycerol, a major content which forms oil that further use in biodiesel production. Biomass of several resources acts as an alternative source for fuel production in which various crops as food crops, parts of plants, crop wastes or fruits, agricultural garbage, leaves and algae are an excellent source of biofuels (biodiesel and bioethanol) (Sheehan et al., 1998).

Microalgae is capable of completing an entire growth cycle within a few days, as they reproduce themselves using photosynthesis to convert solar energy into chemical energy. The Growth rate of microalgae can possible in the presence of sunlight and simple nutrients, to enhance growth rate only good aeration and specific nutrients are sufficient. Biodiesel formed from algae contains no sulfur while perform the same as petroleum-based biodiesel moreover, reducing emissions of green house gases (GHG). The scarcity of crude oil and high prices is a major point to be considered. The biofuel can reduce the pollutant emission and green house gases created a new interest in producing biodiesel using microalgae. This application is an environmentally friendly and economically affordable (Moheimani , 2005).

3. MICROALGAE CULTIVATION

The Unique feature of microalgae is to adapt the resources from environments and to utilize them efficiently in growth so cultivation becomes friendly. For having a high biomass growth which is approximately 50% carbon content a sufficient light is required for photosynthesis (Chojnacka et al., 2004). They can change their internal structure both biochemically and physiologically and form a variety of nutritious compounds by restricting the growth of competitors (Slade et al.,2013). Different microalgae adapt according to their metabolic behavior required by the environment so certain strains grow; 1- Photoautotrophically; solar energy conversion into chemical energy through photosynthesis. 2- Heterotrophically; organic compounds utilizes as producing carbon and energy source. 3- Mixotrophically; organic compounds and CO_2 both are essential for photosynthesis a good energy source (Beal et al .,2012; Nanda et al., 2019).

4. CULTIVATION IN WASTEWATER UTILIZATION AS BIOFUEL PRODUCTION

The Cultivation of microalgae is easy and economical. A perfect system form to cultivate algae in wastewater. Wastewater is an excellent option to cultivate microalgae because of its cost, sustainability, efficient transformation capacity also forms an energy-rich organic C-molecule, certain micro- and macronutrients (N, P) (Ge et al.,2010). Kumar et al (2018) concluded that about 76.8% is a total cost of microalgae biomass production system when high algal biomass yield is required. The wastewater contains organics that can enhance production rate and cost effective ways to cultivate through a mixotrophic system. Microalgae cultivation is also planned where waste heat from cooling waters of fossil fuel generated by electric plants as it reduces fossil fuel inputs to microalgae systems as drying microalgae by natural gas and electricity consumption (Slegers et al., 2013).

Researchers applied certain biotechnological ways to reduce certain toxic pollutants from the environment. Random supply of municipal, an industrial, agricultural, city runoff, all these wastewater can bioremediate by microalgae and utilize various nutrients, to take up inorganic nitrogen (NH_4, NO_3) and phosphorus. All these wastewater sources act as substrates in microalgae growth during cultivation act as nutrient removal. The production of microalgae strongly affected by stains selected climatic conditions and the layout of a production system or reactor design. The 1950s, fast growth rate algae are selected showing ideal behavior in response to certain climatic conditions, nutrient concentration, light, pH and salinity. *Chlorella sp*. and *Senedesmus sp.* are cosmopolitan genus found mainly in all the water stocks as natural water bodies, wastewater, and open system. These stains can easily adapt even the nutrient supply is high (nitrogen or organic) and in extremely drastic environmental conditions (Pittmans et al., 2011). *Chlorella vulgaris* can successfully bioremediate wastewater discharge from a steel plant at a rate of 0.022 g NH_3 l per day (Yun et al.,1997). (Table 3,4).

5. SYSTEMS ADAPTED FOR MICROALGAE CULTIVATION

Open culture (lakes and ponds) and closed culture (photo-bioreactors) systems both are adapted to cultivate microalgae. A photobioreactor (PBR) in which phototrophs as algae, carry out photobiological reactions. Open systems are less cost effective as compared to closed systems. In open pond systems weather conditions, water level up to 15cm to receive proper solar energy and CO_2 from 0.03-0.06% is the basic requirements that would be fulfilled. PBR is adaptable on the bases of microalgal strains being cultivated as shape and design, culture conditions, low CO_2 lose high density production in algal biomass. Richmond scientists, conclude that a closed system has an advantage over the open system as it has 8 times higher productivity and cell concentration that of 16 times higher (Nanda et al.,2019).

6. FLUE GAS TREATMENT WITH MICROALGAE

Flue gases emit regularly from power plants constitute nearly 7% of total CO_2 emission in the world (Kumar et al., 2017). CO_2 acts as a source of growth in microalgae and diminishing potential in the GHG emission strategy. Photosynthesis is chemically electrolysis: a breakdown of water into hydrogen and oxygen. Many unicellular green algae can produce H_2 by using water and sunlight as an energy supply (Zeiler et al.,1995). A researcher reported that certain microalgae, (*Monoruphidiumminutum*) can efficiently utilize flue gases that contain high amount of carbon dioxide, sulfur and nitrogen oxides to obtain biomass. Green algae can fix CO_2 by solar energy about 10-50 times more as compared to other terrestrial plants. Microalgae, can produce biodiesel by lowering the CO_2 emissions as the released amount is equal to the amount evolved during photosynthesis and growth so, it is a carbon saving source. This is how microalgae can manage the CO_2 level in the atmosphere and also producing energy. The selection of strains of microalgae in a biological CO_2 fixation system also plays a vital role and a remarkable point to consider. Some microalgae stains as *Chlorella vulgaris, Scenedesmusobliquus and Chlorella Kessleri* show high growth in a medium when the CO_2 level is up to 18 %. The high tolerance capacity of microalgae makes it a promising energy candidate over other measures. A higher amount of CO_2 utilization and chemically rich compounds are formed in the presence of sunlight. Microalgae can remove the CO_2 from different sources of polluted air or flue gases present in the atmosphere whether it is industrial exhausted gases or maybe soluble carbonate salts (Sakai et al.,1995). CO_2 assimilation depends largely on the selection of species, economically feasible. As the biological mitigation system truely adds advantage if it is planned near power plants.

Heavy metals present in flue gases coming from the combustion of coal considered the main issue when microalgae utilize a flue gas during cultivation . Presence of heavy metals in wastewater can also be noted as it can change biodiesel quality, by-products and biofuel production is also disturbed (Morais et al., 2007).

7. MICROALGAE TREMENDOUS ROLE IN BOD AND COD OF WASTEWATER

One of the major issues is industrial wastewater released in water bodies creates pollution in the environment. Wastewater mainly consists of contaminants either chemical or biological in our surroundings. The anthropogenic activities, agricultural practices, wastewater collected from the urban area all contribute to eutrophication in aquatic life (Hong et al., 2011). Microalgae strains are evaluated to remove such contaminants. COD and BOD likely indicate to what extent the organic pollutant present in water and wastewater. It is reported by Sekaran et al, as 87% of total COD removal, 96% of total BOD observed in Synechocystis sp. of algae from tannery wastewater inoculated in a batch reactor. Wang et al.,(2010) report removal up to COD 50-83.0%, Chen et al.,(2003) report COD 50% (Sekarana et al.,2013).

8. BIOREMEDIATION ROLE OF MICROALGAE

The Industrial sector increases its direct impact on global warming; groundwater level reduces, melting of icecaps all environmental issues draw a focus to reduce it by an ecofriendly and a renewable way. WHO (World Health Organisation) and CPCB (Central Pollution Control Board , India) both organization conduct a survey over a total sewage water treated about 31-35% at secondary level in Asia and urban sectors while rest of water approximately 65-69% is responsible for oxygen depletion, loss of key flora and fauna species, algal blooms plus water bodies degradation (Fig.1,2). Minimal infrastructure, economically convenient measures selection is preferred in advance biological technology. Bio-treatment is selectively the best option to remove a contaminant or pollutants. A wide range of biogenic compounds releases from industrial effluents viz, chemicals, pharmaceuticals, plastics etc. Phenols, dyes, paints and hydrocarbons are some solid emissions from mills. Regular measures taken in developing nations to remove various nutrients discharge in wastewater whose main supply from high surface wastewater (runoff, stormwater). Efforts are taken but not as a serious matter and the amount of wastewater discharge increase regularly (Yun et al.,1997). Hypertrophication or (Eutrophication) , is a phenomenon in which accumulation of organic matter, decomposing organisms utilize them to the extent depleting the oxygen present in water and cause the death of other organisms. The nutrients (NH_4^+, NO_3^-, PO_4^{3-}) found in secondary wastewaters are the cause of eutrophication in natural water bodies. Frequently, they degrade the water quality which finally leads to a disturbance in the aquatic ecosystem (Ugarte et al., 2003). Measures are taken continuously, to clean such a wastewater supply at primary, secondary and tertiary levels. Conventional wastewater treatment includes physical treatment, Chemical treatment and biological treatment. The main attention is drawn in case of a specific contaminant are removed from wastewater as well as the control of nutrients from them. Photosynthetic aeration, microalgae continue to try to reduce aerobically hazardous substances with a low cost and a risk of contaminants volatilization. The procedure microalgae apply in treating industrial wastewater is much convenient (Varsha et al.,2011). The treatments adapted for wastewater purification or nutrients removal are nevertheless membrane filtration, electro-kinetic coagulation, ionization, catalytic oxidation, chlorination and many more practices regularly. These methods do not touch standards just sludge left behind moreover limit the government standards as economically strict complicated and expensive. Organic matter present in a wastewater is not efficiently removed by treatments especially Nitrogen, Phosphorous while some obstinate organic compounds are still left (Khan et al.,2005)..Microalgae are considered as the best among microorganisms or Bio-resources attracting more limelight in a new era due to higher and faster growth ability, non-arable land area is used, low water uptake and cultivation conditions low in cost as well. Microalgae, efficiently utilize all the contaminants present in wastewater and act as a nutrient or feed for algae. Stains that are well reported in phycoremediation are *Chlorella, Arthrospira, Oscillatoria, Botryococcus, Nostoc, Phormidium, Senedesmus,Anabaena, Nitzschia* and many more (de et al.,2010).

9. ENHANCING THE REASON FOR BIOREMEDIATION GROWTH

A wide variety of organic carbon, nitrogen, phosphorous is some of the serious pollutants present in different wastewater ways. Nitrogen and phosphorous are main elements that can capture from waste supply, act as nutrients. These form fertilizers in terrestrial plants, a major product for the environment. Bio-based products including food additives, making cosmetics, proprietary foods, manure, animal fed etc. (Ruiz-Marin et al., 2010). Nitrogen, the role is tolerable for soil but high level of nitrogen is present in wastewater supply its toxicity causes serious algal blooms, disturbance in biodiversity and loss of oxygen. Keep a check on various nitrogen supply is a difficult task because of a variety of inputs in water and waterways. Microbes and plants can absorb nitrogen for further formation of biomass from both water or soil. This biomass decomposes by time and again acts as manure to soil in the form of urea, ammonia etc. Microalgae have a distinctive feature so it is naturally capable of removing nitrogen, phosphorous and excessive CO_2 from any water source (Table 2). Phosphorous, another important nutrient whose supply is expected to be depleted by 2033. Rock phosphate reserves of phosphates lie at margins used in agriculture also in soil they formed cations (insoluble complexes) and its deficiency increases with time (Safonova et al.,2004). In microalgae, Phosphate collects in form of polyphosphate bodies stored inside organelle, acidocalcisome. Its accumulation occurs when phosphorous-starved cells overshoot or some time for luxury uptake. A beneficial aspect of selecting microalgae to recover of phosphorous from water, city runoff or various streams because they take it as a feed (Olguin et al., 2012). The wastewater from municipal, agricultural runoff, city waterworks as a rich nutrient source for the algae and cost effective production of biofuels. Water supplementary sources including industries (paper, pulp, rice hulls, carpets) are a rich feed for algal oil. Although apart of some waste in them work as fertilizer . Yang et al (2011) also report that some of the leftover waste if mixed with a*Ettlia oleo-abundans* under anaerobic conditions, give a synergistic response and increase the quality of biomass thus algal oil formed. An increase in algae fed stock leads to bio oil production studied under some stains *Nannochloropsisoculata*, *Dunaliellasalina* and *chlorella sorokiniana*. All wastewater sources (industrial, sewage, municipal) contain a varying degree of carbon, nitrogen and phosphorous. Agricultural runoff is often found with high nitrogen supplier as compare to industrial wastewaters. Competence of microalgae depends on various factors including pH, temperature, light accessibility, CO_2, O_2 and most important nutrients available in which concentration (Pittman et al.,2011).

10. BENEFITS OF PHYCOREMEDIATION (BY MICROALGAE)

Phycoremediation, phenomena in which plants or algae or microflora for biotransformation of pollutants including nutrients, toxic or heavy metals from any wastewater supply (Dubey et al.,2013) (Fig.2) . Food scarcity, fuel shortage, and cost effectiveness are a major issue in producing biofuels. The algal biomass obtained in algae having high nutritive value and so food fight is negligible while fuel obtained is economic (Richards et al., 2013). Degradation of high sludge, wastewater utilization, the operational setup of phycoremediation is convenient, green house gases or flue gases in environmental pollution, moreover it keeps the bacterial population growth under check. The by-product gets from a microalgae is not injurious moreover phycoremediation can also decrease the level of CO_2 from the atmosphere. Microorganism, involved in a reaction are non- pathogenic so it is safe also. Even some industries are also trying to construct some wastewater treatment plants near the site as this is cost effective and sustainable method (Souza et al., 2012). Microalgae are presumed in cleaning natural water bodies, also the quality of the water improves and their evidenceare reported by many scientists.

11. BIOMASS PRODUCED BY WASTEWATER REMEDIATION

Biomass produced by microalgae under wastewater treatment is present since the1960s. They are efficient in taking nutrients from wastewater source, and utilize carbon, nitrogen and phosphorus because they act as nutrients in them (Pittman et al., 2011). The procedure adopted in biomass production is mainly a small scale named waste stabilized ponds or high rate algal ponds for treatment of wastewater . More emphasis on microalgae growth is given to lipid productivity rather than biomass production it discusses recently in algal based biofuel sector. An increase in biofuel can also affect the biofuels viability. Algae grown in wastewater can report about moderate lipid production around less than 30% DW while high lipid productivity up to 505 mg -1L-1 day. Mostly, it is estimated that unicellular forms of low density microalgae are more capable in the production of biofuel and remediation of wastewater. Biomass is collected further by filtration, sedimentation, centrifugation and flocculation (Pittman et al.,2011). Harvesting of microalgae depends on various factors as algae stains, cell density and culture conditions. Microalgae is a small size 1-30 micrometer, a negatively charged, concentration nearly 0.3-5 g/l, and has a specific density the same as that of culture medium. Due to these reasons it can dispersedly suspend in media (Riano et al.,2011). Microalgae have a much higher capacity is taken up inorganic nutrients studies found that they can be grown in mass cultures in bioreactors also. In general, the biological processes are much convenient compared to physical and chemical which are expensive to be implemented in some places and may cause secondary pollution also. Inorganic salts as nitrate, ammonium and phosphate ions can left in wastewater even after treatment. Biological degradation of such compounds from wastewater by anaerobic and aerobic both processes. It disturbs our aquatic life and algal blooms. Various wastewater treated by some microalgal stains consider an important source for remediation (Table 4).

12. BIOFUEL: NON-RENEWABLE ENERGY SOURCE

The renewable fuel standards (RFS), American Environmental protection agency in 2007 act says that the quality and potential of a microalgal biodiesel meet the renewable fuel standard requirement it required 15.2 billion gallons of domestic alternative fuels in year 2012, which compete for about 2 billion gallons from advanced biofuel and the decrease in nearly 50% of green house gases emissions than that of petroleum-based fuel used for transportation (Griffiths et al.,2009). Microalgae due to its tremendous roles contribute to maintaining ecological balance and control the increase in pollution found in environment. It acts as a promising feedstock for biofuel production with a high production rate within a lower agricultural area as compared to first and second generation biofuels. That's why it's a remarkable feature over other third generation fuel sources (Molina et al., 2013). Microalgae as a sustainable option as the production of biofuel involves natural sources of sunlight, water and CO_2/O_2 are continue for a longer time period is a better option for biodiesel and bioethanol production. These have the potentials to even replace fossil fuels which are economically sustainable steps and a high decrease in a greenhouse gases or flue gas emissions (De et al., 1992). First and second generation biofuel suppliers a biological feedstock (Corn, sugarcane, sugarbeet, wheat while sunflower, animal fats, coconut produced biodiesel) a source of biomass an end product of biodiesel, ethanol and methanol.

Table 1. Lipid Content found in various microalgae species.

Microalgae Species	Lipid Content (% dry weight)	Lipid productivity	References
TetraselmisSueica	15-23	27.0-36.4	Christi et al.,2007
Schizochytrium Sp.	50-57	-	Christi et al.,2007
Nitzschia Sp.	45-47	-	Christi et al.,2007
Nannochloris Sp.	20-56	60.9-76.5	Christi et al.,2007
Botryococcusbraunii	25-75	-	Rodolfi et al.,2009
Neochlorisoleoabundans	29-65	90.0-134.0	Rodolfi et al.,2009
Chlorella sp.	10-48	42.1	Christi et al.,2007
Cylindrotheca sp.	16-37	-	Rodolfi et al.,2009
Nitzschia sp.	16.0-47.0	-	Christi et al.,2007
Tribonema minus	48-50.23	-	Christi et al.,2007
Monoraphidiumcontortum	20-22.20	-	Rodolfi et al.,2009
Ankistrodesmusfalcatus	24.0-31.0	-	Rodolfi et al.,2009
Dunaliellatertiolecta	16.7- 71.0	-	Minowa et al.,1995
Senedesmusdimorphus	16-40	-	Mata et al.,2010, Satyanayana et al.,2011
Chaetoceroscalcitrans	22-39	-	Mata et al.,2010 Satyanayana et al.,2011
Prymnesiumparvum	22-38	-	Satyanarayana et al.,2011
Tetraselmissuecica	15-23		Satyanarayana etal.,2011

Table 2. Microalgae- to- biofuel a industrial level solutions; some alternate issues.

Features	Points to remember
Light	Pulsing Light-emitting diode(LEDs), PBRs Microlensed
Nutrients	Wastewater, utilize flue
Temperature	IR glass/plastic, using cool water
Dewatering	Filamentous species or settling species
Oil production	Excretory pathways need genetic modification
Costs	Byproducts are valuable, PBR designs

Table 3.Appropriate option algae for mass culture (.Satyanarayana et al.,2011)

Algae Characteristic	Advantages	Disadvantages
1-Growth in extreme conditions.	Lower issues with competing certain s pecies and predators.	Limited number of species available. Large scale culture need maintenance (i.e.cold weather)
2- High growth rate	Contribute competitive advantage over com- Species and predators. Low pond area needs.	Growth rate is inverse of cell Size; faster growth in cells
3- Filamentous morp-hology, cell size increase	Decrease in harvesting costs	Small in size.
4- Ample tolerance over Environmental conditions.	Reliable cultures show fewer culture conditions	Large cells grow moderate than. smaller ones.
5- Tolerance of shear force	Low cost pumping and mixing methords Applied.	Secondary metabolites as a byproduct , it affects the normal
6- High cell product content	Higher value of biomass	Growth (High concentration Of metabolites slower the growth)

Table. 4. Some microalgae successfully used in treatment of wastewater.

Microalgae	Types of wastewater treated	References
1-*Chlorella , Senedesmus, Ankistrodesmus*	Olive oil and paper industry wastewaters	Pinto et al.,2003
2-Ankistrodesmus braunii, Senedesmus quadricauda, Lyngbyalagerlerimi	Phenols in olive oil mill wastewater	Pinto et al.,2003,Allen 1968
3- Senedesmus (bijugatus, rubescens, bicellularis, intermedius, obliquus, quadricauda)	Removal of ammonium and alkalinity by anaerobic digestion, nitrogen and phosphorous	Chinnasamy et al.,2010
4-Spirulina platensis	Domestic wastewater treatment	Laliberte et al.,1997
5-Chlorella pyrenoidosa	Azo dyes from wastewater	Jinqi 1992
6- Chlorella sorokiniana, Euglena virdis	Wastewater treatment	Hemendez et al 2006
7- Polytomella sp., Carteriasp.,Lepocynclis ovum	Municipal and Dairy wastewater	Zhu et al.,2013
8-Oscillatoria quadripunctulata	Sewage wastewater	Chinnasamy et al.,2010
9- Chlamydomonas sp., Gloeocystis vesiculosa, Nitzschiasp., Senedesmus spp., Navicula sp.	Carpet mill wastewater	Zhu et al.,2013
10-Chlorella zofingiensis	Piggery wastewater	Hongyang et al.,2011
11- Chlamydomonas sp.	Industrial wastewater	Ruiz-Martinez et al., 2012; Wang et al.,2010
12-Chlorella pyrenoidosa	Soybean processing wastewater	Sekaran et al.,2013
13-Chlorella vulgaris, Senedesmus obliquus	Urban wastewater	Ruiz-Martinez et al., 2012,

A large area is required to grow all these oil crops but a fossil fuel competition is still the same and the demands of the fuel for transportation are still the same. The improvement is shown only if the third generation biofuel microalgae is used as a biological feedstock the land requirement in cultivation is less while the production of biomass is the same (Vinod et al.,2018). Even the magnitude of microalgae biofuel is much higher than other feedstocks from oil crops approx. 91% (L/ha) comparing to other fuel sources.

13. USE OF MICROALGAE AS FOOD FEED AND BIO PRODUCTS

Native use of microalgae as a food source is under consideration from an era. Even some species of green algae use as a food fed (Duong et al.,2015). Especially, the protein rich supplements are popular and a complete diet, important bioproducts include naturally fond antibodies. In US$1.25 *109 each year consumption of bioproducts which are generated by dry algal biomass. Natural products stock of algae used as cosmetics and medicinal products. Microalgae can produce certain biologically active important pigments such as chlorophyll, carotenoids, phycobiliproteins and astaxanthin. They are effective in neuronal disorders, tumorigenesis and optical diseases. Algal cells consist of packages of lipids which depend upon species, these lipids form glycerols, esterified sugars to different types of fatty acids (12-22 carbon atoms).Different stains of microalgae shown lipid productivity in Table 1. Commercially benefits taken into consideration and some species are cultured at industrial level include Aphanizomenonflos-aquae, Chlorella and Arthrospiradue to its high protein and health enhancing factors.

14. COMPOUNDS ORIGINATED BY MICROALGAE

Carotenoids a class of compounds contains Phycobiliproteins, Phycocyanin, phycoerythrin, B-carotene, lutein and astaxanthin. Some species as Haematococcuspluvialisa rich source of astaxanthin, Dunaliellasaline produces B-carotene having 10-14% dry biomass. Sterols found in species Pavlova, Chaetoceros, Amphora, Euglena gracilis and Thalassiosira. they show some health benefits as hypo-cholesterolemia, anticancer, anti-inflammatory and neurological diseases like Parkinson disease (Sathasivam et al., 2017;Srigley et al.,2015).

15. CONCLUSIONS

From this review, we can conclude that the certain stains of microalgae can efficient in making a biofuel which is parallel to a normal diesel (quality wise) used in transportation. The scarcity of fossil fuels is a crucial problem. Less time consume and easy cultivation methods arise day-by-day using microalgae can solve a problem of fuel. The wastewater treatment is always a serious issue, so microalgae shows a good tolerance towards certain injurious heavy metals. The suggestion for the remediation problem is better to cultivate the microalgae near a wastewater sites so, the dual role of microalgae is more valuable. Even the BOD and COD values show elevation if treated with microalgal stains. Bioenergy compounds and valuable proteins, enzymes, certain sterols obtain by algal species. To save our planet from water scarcity, flue gases, shortage of fossil fuels all work by applying phycoremediation step. Highlighting, the main biomass yield is much more than any other crops one of the important environmental friendly ways.

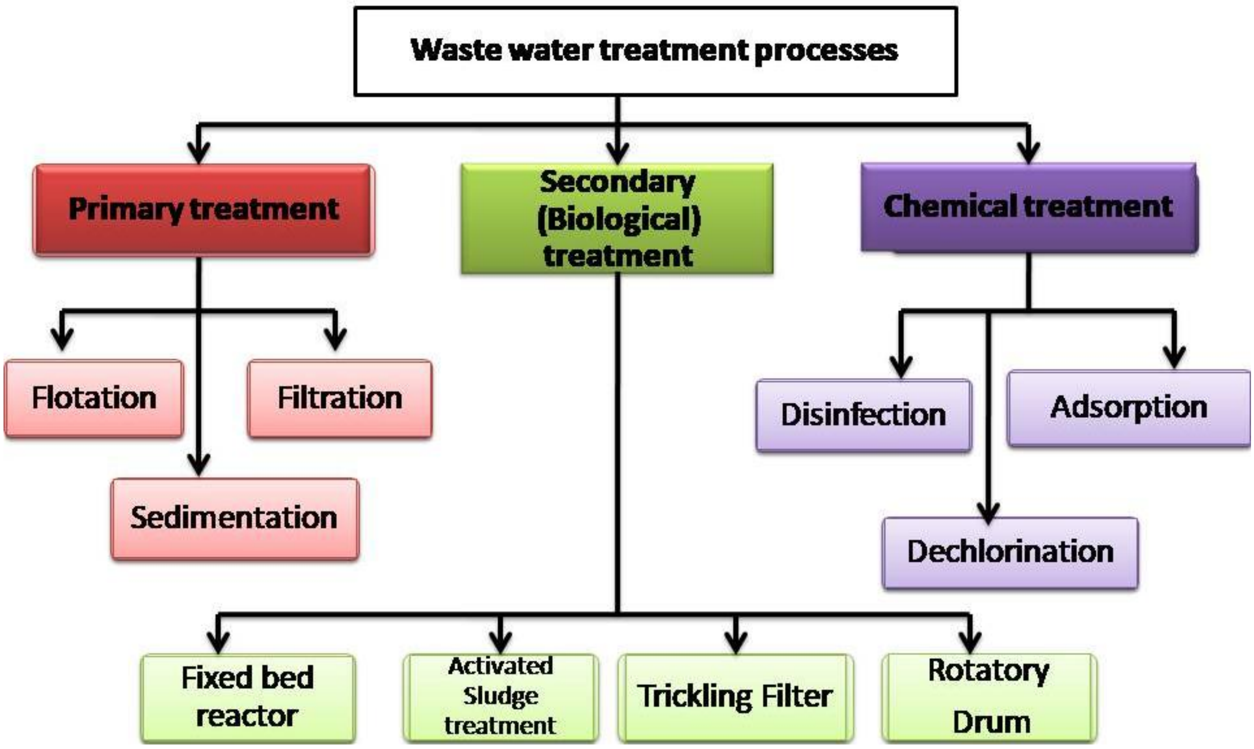

Fig 1: Summary of different methods adopted for treatment of waste water

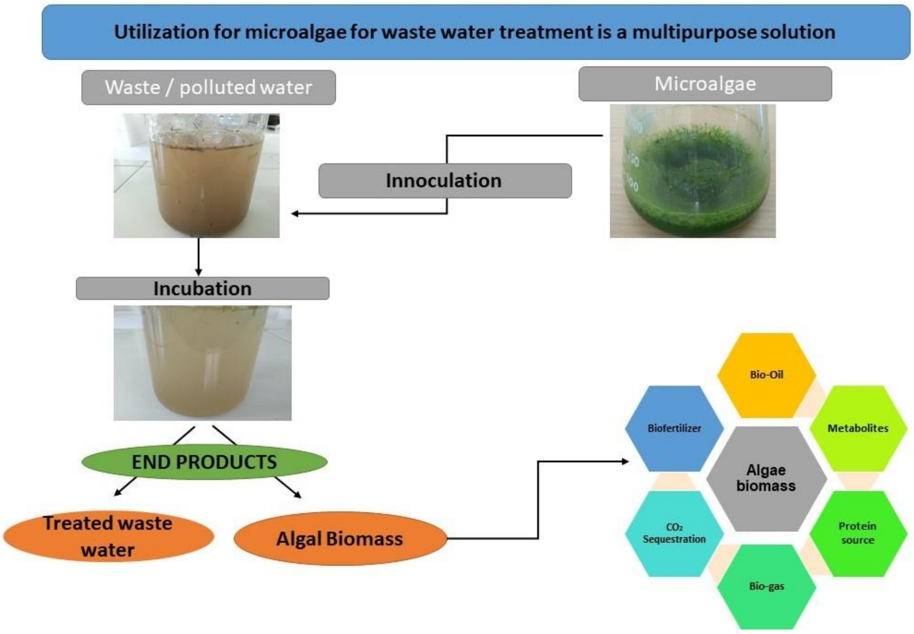

Fig. 2: Outline of wastewater treatment by microalgae and associated application of algal biomass

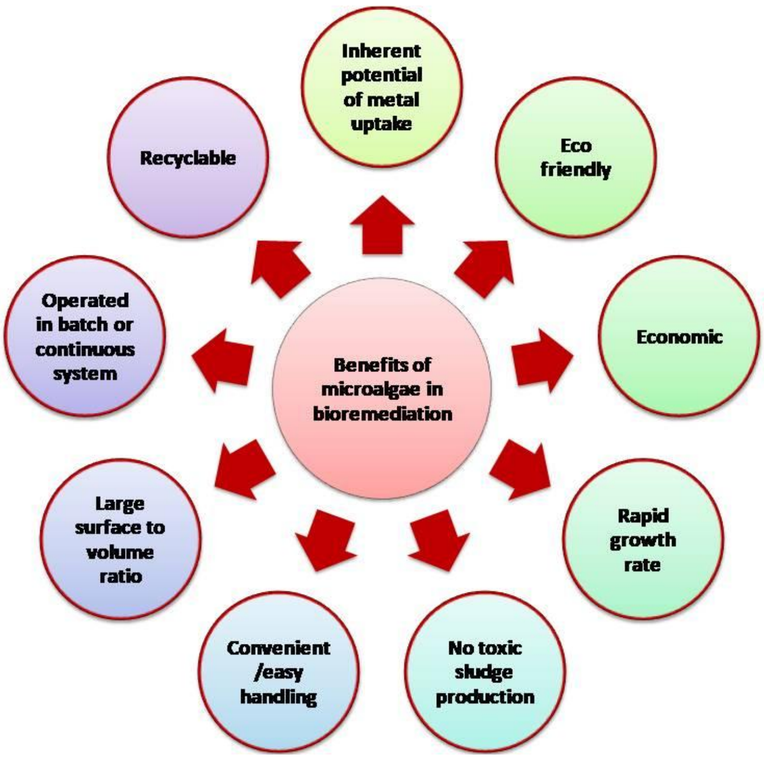

Fig. 3: Advantages associated with utilization of microalgae for bioremediation

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