Microalgae are considered to be futuristic raw material for establishing a biorefinery because of their potential to produce multiple products. A new biorefinery-based integrated industrial ecology encompasses the different value chain of products, co-products, and services from the biorefinery industries. Cross-feeding of products, co-products and power of the algal biofuel industry into the allied industries is desirable for improving resource management and minimization of the ecological footprint of the entire system. The biomass, after the oil has been extracted from it, can be used as animal feed, converted to fertilizer and for power generation. The power generated can then be put back to producing more biomass. The CO_2 released by the power generation plant can be used again for the production of algal biomass, thus reducing CO_2 in the atmosphere. Selected species of microalgae (freshwater algae, saltwater algae and cyanobacteria) were used as a substrate for fermentative biogas production in a combined biorefinery. Anaerobic fermentation has been considered as the final step in future microalgae based biorefinery concept [34].

B. Wastewater treatment

Photosynthetic microorganisms such as microalgae can use pollutants as nutrients (N, P and K) and grow in accordance with environmental conditions, such as light, temperature (generally 20-30 ^{0}C), pH (around 7.0), salinity, and CO_2 content. On the other hand ecofriendly pollutant removal is a major issue in current day research. Many researchers consider microalgae as green technological medium for pollutant removal from wastewater. Removal of organic and inorganic pollutants (NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, CO_2, Cd, Zn, Ni, Co, Mn, Cu, Cr, U, Hg(II), Cd(II), Pb(II), B, TBT (tributyltin), phenols and Azo compounds) from wastewater by different algae is shown in Table 1.

Table: 1 Removal of inorganic and organic pollutant from wastewater by different algae

Microalgae species	Pollution control
Anabaena, Oscilatoria, Spirulina, S. platensis	NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}
Anabaena sp.	2,4,6-trinitrotoluene
Ankistrodesmus sp, *Scenedesmus sp, Microactinium sp, Pediastrum* sp,	CO_2
Chlamydomonas reinhardtii	Hg (II), Cd(II), Pb(II)
Chlorella sp.	Boron
Chlorella miniata	Tributyltin (TBT)
Chlorella vulgaris, Chlorella sp.	Tributyltin (TBT)
Chlorella vulgaris	Azo compounds
Chlorella vulgaris	NH_4^+, PO_4^{3-}
Chlorella spp.	P
Chlorella vulgaris	Cd, Zn,
Chlorella vulgaris, Scenedesmus rubescens	N and P
Chlorella salina	Co, Zn, Mn
Coelastrum proboscideum	Pb
Isochrysis galbana	NH_4^+
Ochromonas danica	phenols
Oedogonium hatei	Ni
Oedogonium sp, *Nostoc sp.*	Pb
Oscillatoria sp. *H1*	Cd(II)
Phormidium bigranulatum	Pb(II), Cu(II), Cd(II)
Phormidium laminosum	Cu(II), Fe(II), Ni(II), Zn(II)
Scenedesmus quadricauda	Cu(II), Zn(II), Ni(II)
Spirulina platensis	Cr(VI)
Streptomyces viridochromogenes, Chlorella regularis	U
Ulva lactuca	Pb (II), Cd (II)
Undaria pinnatifida	Ni, Cu

There are several reasons for the cultivation of microalgae in wastewater such as: (i) cost-effective treatment, (ii) low energy requirement, (iii) reduction in sludge formation, and (iv) production of algal biomass for biofuel production. Microalgae are efficient to remove different types of pollutants and toxic chemicals such as nitrogen, phosphorous, potassium, nitrite, silica, iron, magnesium and other chemicals from municipal and industrial wastewater. In addition, microalgae have high capacity to accumulate heavy metals (selenium, chromium, lead), metalloids (arsenic) and organic toxic compounds (hydrocarbons) to form microalgae biomass which subsequently can be used for biofuel production. The Chlorella spp. has diverse range of different pollutant compare to other microalgae. Other several algae such as *Ourococcus multisporus, Nitzschia cf. pusilla*, *Chlamydomonas mexicana*, S. *obliquus*, *C. vulgaris,* and *Micractinium reisseri* were efficient to remove nitrogen, phosphorus, and inorganic carbon. The highest achieved capacity *C. mexicana* for removal of nitrogen, phosphorus, and inorganic carbon were 62%, 28% and 29%, respectively. Simultaneously the lipid productivity and lipid content were reported 0.31±0.03 g/L and 33±3%, respectively. Using microalgae for combined renewable energy production along with efficient wastewater treatment systems at a low cost, offers an innovative promising direction for an integral approach to water and energy problems and climate change mitigation.

VII. CONCLUSIONS

Algae are the fastest growing organisms in the world. Microalgae are known for faster growth rates than terrestrial crops. Additionally, the microalgal biomass can be harvested after CO_2 fixation to produce microalgal biofuel that can be utilized as a renewable or sustainable energy source. The per unit area yield of oil from algae is estimated to be from 18,927 to 75,708 litters/per acre, per year; this is 7–31 times greater than terrestrial crops although there are claims of higher yields of up to 100,000 liters per hectare per year.

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