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## APPLICATION OF MICROALGAE FOR NUTRIENT RECOVERY FROM WASTEWATER

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### ABSTRACT

Dumping of wastewater often results in high nutrient stocking into aquatic environments, which may be dominant to favorable conditions for unwanted phytoplankton blooms. Microalgae are well-organized in removing nitrogen, phosphorus, and heavy metals from wastewater under controlled environments. Improbability substantial nutrients in the wastewater stream can be top to cultivate microalgae for biofuel production, the nutrients also be removed, therefore meaningfully reducing the risk of damaging phytoplankton overgrowth. Microalgae also have the capability to fix the excess Carbon dioxide (CO<sub>2</sub>) present in the environment and release the oxygen (O<sub>2</sub>) and decrease the problem of Global warming. In conclusion, novel algae cultivation technologies effective for biofuel production and nutrient recovery in contaminated water bodies are deliberated. On this review paper summarizes the key nutrient components of wastewater streams, the mechanisms of algal nutrient uptake, nutrient removal performance of various type

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of microalgae when cultured in wastewater, and current microalgae production systems. Still the technology existing (photobioreactors, harvesting, downstream) must be improved to reduce the land requirement and the hydraulic retention time, but the current technology is ready to be demonstrated at large scale, so that the first initial facilities based on this technology have been recently developed.

**Key wards: Microalgae, Wastewater, Nutrient recovery, CO<sub>2</sub>, Sunlight, harvesting**

## 1. INTRODUCTION

Today's world most critical environment problem is water pollution. In the last few periods, the rapid population progress, industrial mutiny and development have managed to numerous forms of environmental pollution. The discarding of raw wastewater (e.g., industrial raw water, municipal, palm oil mill discharge, storm sewage, household wastewater, etc.) directly into water bodies such as rivers, lakes and oceans is considered a simple and low-cost discharge method in societies where wastewater disposal is not well synchronized [1]. Recently, microalgae has been purchase interest owed to its two fold character of bioremediation of wastewater as well as generating algae biomass, which can be recycled in bioenergy generation, pharmaceuticals, organic fertilizer and animal feed.

The main objective of this review with respect to microalgae-based waste water

treatment is: Recovery of nutrients from wastewater, Environmental variables affecting growth with open pond system, Current application and low cost microalgae growth with small scale and effective methods and tests for water.

## 2. Microalgae:

Microalgae similarly to microphytes are microscopic algae, it do not contain roots, branches, or grasses. They are generally modified to an environment dominated by sticky forces. It can be microscopic in size because can't see by naked eye. They use solar energy to moderate inorganic nutrients to organic matter hence producing biomass, that's why it's photoautotrophic. Overall microalgae can fixation of nutrients like nitrogen and phosphorus, it's a direct function of regular irradiance. Microalgae can adjust their internal structure by both biochemical and physiological change (Figure 1) [3].

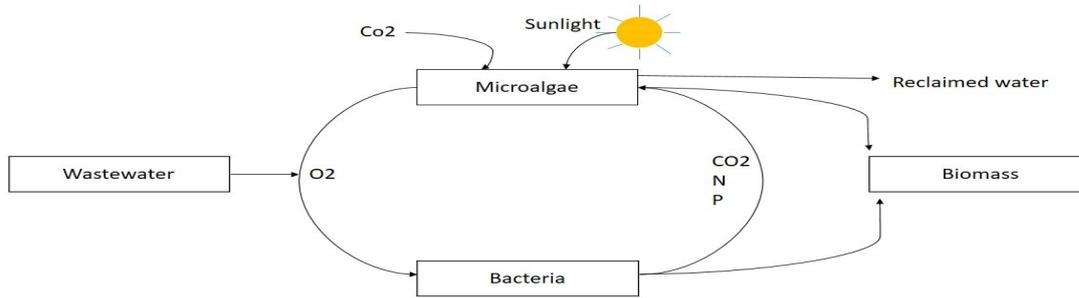


Figure: 1: Basic principles for the microalgae production join up with wastewater treatment [2]

Table 1: Microalgae were used for recovery of nutrient from wastewater with their habitat, application and related species

Algae group	Species	Habitat	Wastewater type	Application	Reference
Prokaryotic, blue-green algae (Cyanobacteria)	<i>Arthrospira, Microcystis, Oscillatoria, Anabaena azollae, etc.</i>	Ocean, fresh water, damp soil, etc.	Domestic wastewater, industrial wastewater (Textile, Winery, Tannery, Paper mill, Olive mill, etc.)	Mariculture, foods, fuel, fertilizers, colorants, production of secondary metabolites (toxins, vitamins, enzymes and pharmaceuticals)	[4, 5,6,7].
Eukaryotic, green algae (Chlorophyceae)	<i>Botryococcus, Chlamydomonas, Chlorella, Volvox etc.</i>	Generally developed in fresh water (95%), and the recreation salty water	Industrial water, sewage etc.	Antioxidant, cosmetics, Antibacterial, Anticancer and nutraceuticals.	[8, 9, 10, 11].
Eukaryotic, brown algae (Phaeophyceae)	<i>Dinobryon, Mallomonas, Ochromonas, Dictyota etc.</i>	Marine environments, rocky coastlines in temperate region of the globe.	Industrial wastewater, house waste, local waste.	Alginates (alginic acid)	[12, 13, 14,15].
Eukaryotic, red algae (Rhodophyceae)	<i>Porphyridium, Platoma etc.</i>	Marine environment, rare in fresh water.	Sewage treatment, municipal wastewater etc.	Agar and gelatinous substance, Antiviral agent, Anti-inflammatory, Anti-cancerous.	[16, 17, 18, 19, 20].
Eukaryotic, diatoms algae (Bacillariophyceae)	<i>Asterionella, Cyclotella, Surirella, Epithemia, etc.</i>	Oceans, fresh water like lakes and streams.	Agriculture wastewater (Dairy, poultry, swine, beef feedlot, fertilizer, animal waste and their food, etc.), municipal wastewater.	Oil exploration, forensic examination, Environmental warning, Biosilica pattern group, toxicity testing and eutrophication of aqueous ecosystems.	[21, 22, 23, 24].

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### 3. Wastewater source:

In the past few times, researchers give wonderful efforts put into cultivation of microalgae biomass in wastewater treatment. Studies revealed positive results regarding the potential of utilizing microalgae to remove nitrogen, phosphorus, heavy metal and other elements from wastewaters. The alignments of wastewaters can be different with sources. In this segment, the nutrient components of different wastewater streams (agricultural, municipal, and industrial) are discussed.

#### 3.1 Agriculture wastewater:

Agricultural wastewater, which is largely produced from live-stock production, is another main source of wastewater. Nitrogen and phosphorus rich in wastewater produced from animal farms. Nearly half of the nitrogen in animal waste is in the form of ammonium, and half is in the form of organic nitrogen. Factors like animal food, age, usage, productivity output, management, and location will innocently affect the nutrient content in animal wastewater [25].

#### 3.2 Municipal wastewater:

Municipal wastewater, when increasing development and growth of built-up populations has resulted in higher quantities of municipal wastewater. This type of wastewater has a smaller amount nitrogen

and phosphorus matched with animal wastewater. There are significant amounts of heavy metals (iron, tin, zinc, silver, cobalt and copper) in raw municipal waste. The traditional method municipal wastewater treatment process contains three stages: primary, secondary, and advanced stages [26].

#### 3.3 Industrial wastewater:

Industrial wastewater, it differs depending on the source actions, maximum industrial wastewaters contain more heavy metal pollutants and less nitrogen or phosphorus than other types of wastewater. High metal removal productivity achieve to selection of microalgae strains with high metal sorption capacity is essential.

### 4. Environmental factors growth parameters:

Effective treatment with the microalgae requires a detailed knowledge of several parameters that affect the growth. If one factors diverges drastically then the whole process can go wrong in terms of algal productivity and treatment efficiency and it affected to the economic rate. Chemical, biological and physical factors are also affected to the growth rate. Examples like, physical factors: medium range temperature and sunlight energy source. Chemical factors: presence of nutrients and carbon

dioxide level and pH level, and biological factors: inhibitory substance and competition between two and more species, and virus, bacterial infections [27].

**5. Types of microalgae cultivation techniques:**

Microalgae cultivation is mostly used in commercially of algae-based fuels, water treatment and further needed must be met: low-cost culture media, low cost algae production systems that easily maintained, enough carbon dioxide sources for ideal algae growth, effective algae harvesting methods, and cost-effective and low-energy input algal lipid extraction biofuel and nutrient recover methods. Most of the recent algae cultivation systems can be regarded as into three groups based on their reactor

design: open systems, closed systems, and hybrid systems which are used on land (Figure 2).

**6. Harvesting techniques:**

Microalgae can grow in open wastewater ponds spread with biomass levels of up to 250mg dry weight per liter. In wastewater treatment harvesting technique of microalgae is critical to separate out nutrient and oxygen demand (OD). It's not easily complete, and cultivating process is a cost expensive part. Even though harvesting successfully can be done by centrifugation or filtration, some methods may be too costly or difficult to appliance. Other than chemical flocculation like (biological filtration, alum, ferric chloride, etc.).

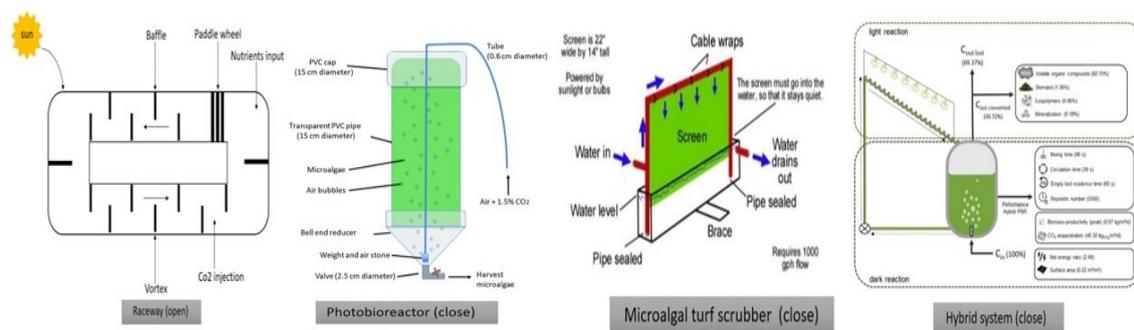


Figure: 2 Current microalgae cultivation techniques [28]

**6.1. Filtration and Centrifugation:**

Filtration, it is the simplest and cost-effective harvesting method. Filtration can be approved either in small or large scale. It can be done by using filter paper in laboratory

scale or using rough screening in a large-scale harvesting of microalgae. It is one of the suitable process for harvesting large microalgae (e.g., *spirulina platensis*) and not succeeds to separate bacteria size (small)

microalgae like *scenedesmus*, *dunaliella* or *chlorella* species [29].

Centrifugation, it can be applied to nearly every type of microalgae. Using the same sedimentation principal but with addition with heightened gravitational force to increase the sedimentation rate. There is rare types of centrifugation technique and it is reliant on the particle size. Tubular bowl centrifugation, provides the well-organized result in harvesting but the capacity is extremely limited. Centrifugation is used mostly in laboratory (small) scale. There are some disadvantages of centrifugation which is microalgae cell's structure can harm during to the exposure to high gravitational forces.

### 6.2. Sedimentation and Floatation:

Using sedimentation or floatation process the biomass can be concentrated already in the water, which in turn can be transferred. Floatation, of unicellular algae without flocculation can also be exceedingly difficult due to the hydrophilic cell surface on which air bubbles will not attach. Adding these chemicals, is that they can cause secondary pollution these main disadvantage [30].

### 6.3 Biological filtration:

Biological filtration means serving of easily harvested filter feeders with microalgae and is subsequently a form of aquaculture.

Complete food chains starting with wastewater have been studied to progress integrated systems able to produce useful biomass simultaneously with emission purification.

### 7. Mechanisms of nutrient removal:

Basics like carbon, nitrogen, phosphorus and, sulfur together with small amounts of trace metals like (sodium, calcium, iron etc.) growth for algae. Between these elements, uptake of nitrogen and phosphorus is acute for algal growth.

#### 7.1 Carbon and Nitrogen:

Autotrophic microalgae can fix carbon (in form of CO<sub>2</sub>) biologically from the air by photosynthesis. Microalgae can also up take carbon in the form of soluble carbonates for their growth and metabolites, also by direct uptake or exchange of carbonate to free CO<sub>2</sub> through a carboanhydrase activity.

Nitrogen is present in wastewater in the form of NH<sub>4</sub><sup>+</sup> (ammonia), NO<sub>2</sub><sup>-</sup> (nitrite) and NO<sub>3</sub><sup>-</sup> (nitrate). The conversion of inorganic nitrogen into organic nitrogen forms can be take out by eukaryotic microalgae via variation. Steps show in **Figure 3** in the transformation of inorganic nitrogen into organic forms. First, translocation of inorganic nitrogen takes places through the plasma membrane of the algal cells with following reduction to nitrate and nitrite by

nitrate and nitrite reductase enzyme. In next step, is the conversion of ammonium into amino acids (glutamine). Nitrate reductase enzyme is utilizing the reduced form of nicotinamide adenine dinucleotide (NADH) to transfer 2 electrons in the reaction for the conversion of nitrate into nitrite. In next step, nitrite is further reduced to ammonium by nitrite reductase enzyme and ferredoxin (Fd)

to transfer 6 electrons in the reaction. All inorganic forms of nitrogen are reduced to ammonium before existence combined into amino acids within the intracellular liquid. At last, glutamine synthase enzyme using glutamate (Glu) and adenosine triphosphate (ATP) simplifies the combination ammonium into amino acids (glutamine) [31].

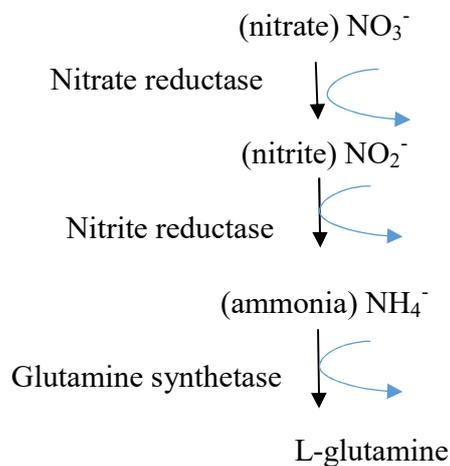


Figure 3: Representation of the conversion of inorganic nitrogen to inorganic form through assimilation [32]

## 7.2 Phosphorus and other nutrients:

Phosphorus is present in lipids, nucleic acids, and proteins also intermediates of carbohydrate metabolism is a result of phosphorus acceptance. Inorganic phosphorus in the form of phosphates plays a key role in the growth of algae cells and also their energy metabolism. Algae metabolisms depend on mostly on inorganic phosphorus in the forms of hydrogen phosphate ( $\text{HPO}_4^{2-}$ ) and dihydrogen phosphate ( $\text{H}_2\text{PO}_4$ ) which is

then combined into organic compounds through a phosphorylation process relating the production of ADP-derived ATP together with energy effort [33].

Other micronutrients, containing silicon and iron, can affect the large quantity of phytoplankton communities. Some micronutrients are toxic for various algal species at highest concentrations. Some algal strains accepting to heavy metals and their possible to absorb metals.

## 8. Challenges and strategies:

Previous broad work has been strongly established that microalgae are economic, efficient and sustainable way to give wastewater. It has a extensive potential to remove major amount of inorganic nutrients, heavy metal, pathogenic organism, chemical toxins and sequesterate atmospheric Co<sub>2</sub> there is need to expand the technology for large scale wastewater treatment such as nitrogen approval could be enlarged if the microalgae were preconditioned by starvation, concentrated algal cultures are used to reduction for the terrestrial and space requirements [34].

Primary strategies of microalgae wastewater treatment are the choice of ideal algal strain and development algal strain improvement by various methods such as lipidomics, genomics, proteomics and metabolomics to make best use of wastewater for higher biomass yield. The significant disadvantages in utilization microbial biomass are its harvesting. Harvesting is one of the greatest challenging processes in integrated microalgae wastewater treatment can be used because of its small size, high dilution rate, and electronegative cell surface charge. Harvesting is a process of sorting out the algae from water, accounting for 30% of total microalgae biomass production cost. While,

they have limitation of high cost, long processing time, high energy needs and low regaining [35].

A biological method bio-flocculation which is an advanced dewatering method has been projected. These processes have quite a few advantages over their free-cell equivalents including high bio-sorption capacity, reside in less space, are easier to handle, and can be used repeatedly for product generation [36].

## CONCLUSION

The recovery of nutrients from wastewaters with microalgae is a dependable process, which can be applied to different wastewater types from sewage to fertilizer. The major challenge today is to establish this type of processes at large scale, at different conditions and by using different wastewater types, different industrial scale developments being in progress. The creation of biofuels is every time attractive, microalgae are seriously significant for chemicals, animal feeding, and agricultural uses. It grasps valuable compounds like (proteins, fatty acids, bio-stimulants, etc.) that permits the development of high yield.

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