Waste Water Treatment Using Micro-Algae - A review Paper

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Abstract—The present study illustrates the efficiency of microalgae based treatment system. Treatment of wastewater with Microalgae based system have the ability to remove nutrients (Nitrogen, Phosphorus and other nutrients), heavy metals, toxic substances (both organic and inorganic), BOD, COD and other impurities present in the wastewater by using the sunlight, CO₂ and impurities like nutrients present in the wastewater. The microalgae also have the ability to fix the excess Carbon dioxide present in the environment and release the oxygen and solve the problem of Global warming. According to the various study, the nutrients removal efficiency of microalgae based wastewater treatment system is very high as it removes 78-99% of Nitrogen and Phosphorus. The treatment system also succeeds to remove 40-65% of COD, BOD and other impurities present in wastewater. The microalgae treatment system is economical, green, and environmental friendly option of wastewater treatment.

Keywords—Microalgae, Nutrient removal, wastewater, Sunlight, CO₂

I. INTRODUCTION

In developing country like India, due to the increasing population and rapid industrialization, the amount of wastewater generated every day is very huge. Due to this, water pollution is one of the most critical environmental problems. For wastewater treatment various conventional methods are used in India but they are very costly and not economical. Nowadays, some new green technical methods of wastewater treatment are being introduced to resolve the problems related to the conventional methods.

During the last 50 years Biological wastewater treatment systems with microalgae have gained importance and now it is widely accepted that microalgal based wastewater treatment systems are as effective as conventional wastewater treatment systems [1]. Cultivation of Microalgae in wastewater for wastewater treatment, pollution control and production of energy from microbial biomass is nowadays common treatment method. Microalgae have become significant organisms for biological treatment of wastewater. Microalgae based treatment system is one of good solutions to solving the environmental problems such as global warming, the increase of ozone hole and climate changed due to its ability to consume high quantity of carbon dioxide in Photosynthesis process to produce oxygen and glucose [2].

Microalgae have the ability to remove nutrients, heavy metals, organic and inorganic toxic substances and other impurities present in the wastewater by using the sunlight, CO₂, and various nutrients. The main advantage of using algal system is that it absorbs solar radiation in the form of energy in its chloroplast cell and takes CO₂ along with nutrients from wastewater to synthesis their biomass and produce oxygen. The released oxygen from microalgae is enough to meet the most aerobic bacterial requirements while metabolizing the residual organics in the treated wastewater. Algae also release a large amount of simpler organic compounds that can be assimilated in aqueous system. The bacteria, in turn constitute an essential source of CO₂ required for algal growth, stimulate the release of vitamins & organic growth factors and change the pH of the supporting medium for algal growth [3].

Determination of Algae Growth Potential is based on the relation of a maximum biomass yield concerning the biologically used nutrients for microalgal growth. In a water body, nutrients could be consumed, partially or totally, depending on the nutritional present in the water [4]. Furthermore, a nutrient-rich discharge like, effluent from the anaerobic digestion process is generally recycled to the head of the wastewater treatment plant and can increase the cost and destabilize the overall treatment process due to the accumulation of phosphorus. Algae are known to grow in wastewater, a possible solution is to co-locate and integrate production of algae with treatment of nutrient-rich wastewater and utilize CO₂...
from power plant flue gas [5]. The microalgae system can treat various types of wastewater like, domestic sewage, industrial waste water etc and reduce the nutrients (Nitrogen, phosphate and other minerals) from the waste water. Removal of Nutrient is an important part of wastewater treatment because rich nutrient effluent discharged into water bodies can result in eutrophication in water bodies[2, 5]. The Figure: I shows the Basic operation principles for the microalgal production combination with wastewater treatment.

![Basic operation principles for the microalgal production combination with wastewater treatment](image)

**Figure: I. Basic operation principles for the microalgal production combination with wastewater treatment [Dalrymple et al.,2013]**

Microalgae based treatments have a number of unique benefits. As an aquatic species, they do not require arable land for cultivation. It means the cultivation of microalgae does not need to compete with agricultural commodities for growing space. In fact, microalgae cultivation facilities can be built on minimal land that has few other uses. The water used in algae cultivation can be fresh water or saline, wastewater, and salt concentrations up to twice that of seawater can be used effectively [6].

II. FACTOR AFFECTING FOR THE GROWTH OF MICROALGAE

a) **Sunlight**

Microalgae are unicellular, photosynthetic microorganisms and they use sunlight in the photosynthesis process. Photosynthesis is the process of converting light energy into organic molecules, which are mainly composed of carbohydrates, CH2O. Sunlight is important to the growth of microalgae and without sunlight microalgae growth has been reduces.

b) **Carbon Dioxide (CO2)**

The increased atmospheric CO2 level is now worldwide accepted to be a major contributor to global warming; its various potential effects are only beginning to be understood [7]. Microalgae use Carbon dioxide and sunlight in photosynthesis activity and release the Oxygen in the environment.

The photosynthesis reaction gives food to the algae. The reaction between sunlight and CO2 shown below:

\[
6 \text{H}_2\text{O} + 6 \text{CO}_2 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2
\]

Microalgae can fix CO2 from three different sources, viz. atmospheric CO2, discharge gases and soluble carbonates. During the photosynthetic process, microalgae utilized CO2 from the atmosphere as a carbon source to grow and releases oxygen. According to the studies microalgae cells contain approximately 50% carbon, in which 1.8 kg CO2 are fixed by producing 1 kg of microalgal biomass [7]. For the fixing of CO2 microalgae are considered as more efficient than terrestrial plants.

c) **Nutrients (Nitrogen, Phosphorus and other minerals)**

The use of municipal and industrial wastewater effluent as a nutrient feedstock for the production of algal has environmental and economic benefits [8]. Wastewater nutrients are fed microalgae by different nutrients like nitrogen, phosphor, ammonia, sulphur, iron, toxins and all the metals in wastewater to production of microalgae biomass [2]. Phosphorus and Nitrogen are the most essential nutrients for the microalgae growth. Besides carbon, nitrogen is the second most important nutrient to microalgae. Phosphorus is another macro-nutrient essential for growth, which is taken up by algae as inorganic orthophosphate [9]. **Table: I.** shows the major nutrient removal efficiencies by microalgae cultivation.
Table: I. Summary of major nutrient removal efficiencies by algal cultivation [Wang et al., 2010]

<table>
<thead>
<tr>
<th>Algae species</th>
<th>Wastewater characteristics</th>
<th>N (%)</th>
<th>P (%)</th>
<th>Carbon</th>
<th>Retention time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algal–bacterial symbiosis (Chlorella + Nitzchia)</td>
<td>Settled domestic sewage</td>
<td>92</td>
<td>74</td>
<td>97% BOD, 87%COD</td>
<td>10 h</td>
</tr>
<tr>
<td>Chlorella pyrenoidosa</td>
<td>Settled domestic sewage</td>
<td>93.9</td>
<td>80</td>
<td>NA</td>
<td>13 days</td>
</tr>
<tr>
<td>Cyanobacteria</td>
<td>Secondarily treated domestic effluent + settled swine wastewater</td>
<td>95</td>
<td>62</td>
<td>NA</td>
<td>1 day</td>
</tr>
<tr>
<td>Chlorella vulgaris</td>
<td>Diluted pig slurry (suspended solids content to 0.2%)</td>
<td>54-98</td>
<td>42-89</td>
<td>BOD, 98%</td>
<td>4.5 days</td>
</tr>
<tr>
<td>Chlorella pyrenoidosa</td>
<td>Domestic sewage and industrial wastewaters from a pig farm and a palm oil mill</td>
<td>60-70</td>
<td>50-60</td>
<td>80-88 % of BOD, 70-82 % COD</td>
<td>15 days</td>
</tr>
<tr>
<td>Mixed culture of Chlorella and diatom species</td>
<td>Wood-based pulp and paper industry wastewater</td>
<td></td>
<td></td>
<td>58%</td>
<td>42 days</td>
</tr>
</tbody>
</table>

NA - Not applicable

Other than nitrogen and phosphorus, some other micro-nutrients also required for the growth of the microalgae. Wastewaters have almost all type of micro-nutrients, so waste water helps to growth of microalgae.

d) pH

Microalgal growth rate and treatment of waste water may also be affected by pH of the waste water. Availability of inorganic carbon also affected by pH, even if pH is high for other reasons than photosynthetic CO2-exhaustion, the pH regulates what species of inorganic carbon that is available [9]. Increasing dissolved oxygen concentration and pH cause for phosphorus sedimentation and also ammonia and hydrogen sulphur removal. High pH in algal ponds also leads to pathogen disinfection [1]. Fontes et al (1987) observed that optimal productivity of the cyanobacterium Anabaena variabilis were obtained at pH 8.2–8.4, being slightly lower at 7.4–7.8, decreasing significantly above pH 9, and at pH 9.7–9.9 the cells were unable to grow well [9].

e) Temperature

Temperature is proportional to the availability of sunlight and has little effect when light is limiting. When light availability is not limiting, increase in temperature can increase the rate of photosynthesis, growth/doubling rates are consequently [11]. However, even though light is most often limiting the growth of microalgae, too much light may also cause lowered photosynthetic effectivity, which is known as photoinhibition. Increased temperature enhances algal growth until an optimum temperature is reached. Further increase in temperature leads to a
rapid reduction in algal growth rate [9]. Temperature ranges generally within 20 to 30 °C for the maximum growth of microalgae.

III. REVIEW OF VARIOUS STUDY RELATED TO WASTE WATER TREATMENT WITH THE HELP OF MICROALGAE

Rapid Industrialization and increasing population led to the increase of contaminants (Chemical and Biological) in wastewater. The reduction of anthropogenic nutrient inputs (from agricultural practices, urban wastewater and various industries) in the aquatic systems is required to protect water supplies and to decrease eutrophication process. Their removal efficiencies depend on several factors: (1) microalgal culture, (2) Nutrients initial concentrations, (3) Ratio of nitrogen and phosphorus (N/P), (4) microalgal strain, (5) microalgal growth conditions, (6) nutrients source, and (7) wastewater characteristics [12].

Microalgae can be used to treat both of municipal and industrial wastewater. However, microalgae can be grown in wastewater to removal all pollutants and chemical toxic substances from wastewater such as nitrogen, phosphorous, nitrite, silica, iron, magnesium and other harmful chemicals. Microalgae have huge capacity to accumulate the heavy metals and heavy toxic compounds to form microalgae biomass [2]. The various study conducted to identify the treatment of wastewater using microalgae discussed below;

The work conducted by Dalrymple et al, (2013) showed that there are important benefits to be derived from integrating algal production systems with nutrient-rich waste streams. The energy resulting from algae will play a significant role in providing energy security while important services such as water treatment can be significantly achieved by these systems. It also shows that by the end of 14-day batch culture was removed 94% ammonia, 89% TN and 81% TP with the help of algae [5].

Mahapatra et al, (2013) investigate the treatment efficiencies of the Algae based sewage treatment plant located in Mysore. The study showed moderate treatment levels with 60% total COD removal, 50% of filterable COD removal, 82% of total BOD removal, and 70% of filterable BOD removal. The nitrogen removal efficiency was less. However, a rapid reduction in the suspended solids after a higher euglenoid growth indicates particulate carbon removal by algal ingestion [13].

Sekaran et al (2013), studied on Integrated Bacillus sp. immobilized cell reactor and Synechocystis sp. algal reactor for the treatment of tannery wastewater with CAACO reactor. The effluent after treatment through primary clarifier, chemo autotrophs immobilized cell reactor known as CAACO reactor and removed BOD, COD, TOC, VFA and sulphide, respectively, by 96 %, 87 %, 83 %, 71 %, and 100 %. The residual organics in treated tannery wastewater was further treated in Synechocystis sp. inoculated algal batch reactor. The algal pond was able to discharge treated wastewater of characteristics BOD₅, 20± 7 mg/l; COD, 167±79 mg/l; and TOC, 78±16 mg/l conforming to the discharging standards prescribed by pollution control agencies. The cumulative percentage removal of BOD₅, COD, TOC, VFA, and sulphide in the present investigation were 98 %, 95 %, 93 %, 86 %, and 100 %, respectively [3].

Wang et al (2010) conducted a study to evaluate the growth of green algae Chlorella sp. on wastewaters sampled from four different points of the treatment process flow of a local municipal wastewater treatment plant and how well the algal growth removed nitrogen, phosphorus, chemical oxygen demand (COD), and metal ions from the wastewaters. The study showed average specific growth rates in the exponential period were 0.412, 0.429, 0.343, and 0.948 day⁻¹ and removal rates of NH₄–N were 74–82 %, phosphorus 83–90 % and 50–83.0 % COD were removed for four different types of wastewater. It was also found that metal ions, especially Al, Ca, Fe, Mg, and Mn in centrate, were removed very efficiently. [10].

Chen et al, (2003) investigate Nutrient removal by the integrated use of high rate algal ponds and macrophyte systems in China. The study showed percentage removals for COD were 54.5% in “winter” (8 days) and 44.5% in “summer” (4 days). The mean annual removal of COD was only about 50%. However, the percentage removal of dissolved COD compared to the total COD in the influent was about 73%. Indeed, the HRAP produced an effluent with a low concentration of dissolved COD (about 60 mg/l), but the total COD may be high due to algal biomass. The mean removal performances were about 50% for COD and phosphorus, 75% for TKN and 90% for NH₄-N. This system was especially efficient in removing ammonia from wastewater [14].

Gupta (1985) studied on nitrogenous wastewater treatment
by activated algae and given that it is possible to remove TKN between 69.5%-93.4%, NHJ-N between 77%-98% and urea between 53% to cent per cent for nitrogen loadings between 0.1 g/L day- to 0.37 g/L day. The major NHJ-N removal mechanism was the stripping of ammonia in the range between 52%-66%. It was possible to achieve nitrification at all SRT's and corresponding COD/TNK ratios. The COD removal was found to average between 89.5%- 97.7% for the organic loadings between 0.5 g/L-day to 0.68 g/L-day [15].

IV. CONCLUSION

The study shows the ability of microalgae to uptake the carbon, nitrogen, phosphorus and heavy metal, and microalgae have a potential for the treatment of wastewater for various types of effluent. Sewage and industrial wastewater is naturally enriched in nutrient that can be used for algal growth. It also observed that the major factors that effecting algal growth and treatment efficiency are carbon dioxide and light from all other factors. The various studies conducted to treat the wastewater using microalgae shows that the microalgae reactor has a significance reduction in nutrients, BOD and COD and other toxic chemicals but increase in Total solids due to the growth of microalgae, so it is recommended before discharging the treated wastewater in the stream, it is necessary to remove microalgae from the treated effluent to meet general standards of wastewater discharge. The nutrients removal efficiency of microalgae based wastewater treatment system is very high. The system has a removal efficiency of 78-99% of Nitrogen and Phosphorus. The treatment system also succeeds to remove 40-65% of COD, BOD and other impurities present in wastewater.

REFERENCES


