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Effectiveness of Algae in Wastewater Treatment Systems

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Abstract: Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) play important role in determining the quality of wastewater. Hence it is necessary to calculate COD and BOD of water before setting up of wastewater treatment plant. Algae has been used for decades for various purposes. It is one of the important characteristics is to nitrogen, phosphorus etc., which are harmful for drinking and other purposes but they act as food for algae. Thus in this study COD and BOD analysis is done for sterilized and non-sterilized wastewater after and before treating it with algae in inverse fluidization under aerobic condition, for different time interval and found that percentage reduction in COD and BOD for sterilized wastewater gives greater value than non-sterilized water the reason for this difference being the decrease in the competition between algae and other micro-organism which are present in raw wastewater and COD % reduction is 65-70 % and BOD % reduction is 68.75-70.5%.Organic and inorganic substances which are released into the environment as a result of domestic, agricultural and industrial water activities lead to pollution. The normal primary and secondary treatment processes of these wastewaters have been introduced in a growing number of places, in order to eliminate the easily settled materials and to degrade the organic material present in wastewater. The final result is a clear, apparently clean effluent which is discharged into natural water bodies. This secondary effluent is, however, loaded with inorganic nitrogen and phosphorus and causes eutrophication and long-term problems because of refractory organics and heavy metals that are being discharged. Microalgae culture offers an interesting step for wastewater treatments, because they provide a tertiary bio-treatment coupled with the production of potentially valuable biomass, which can be used for biofuel production. Microalgae cultures offer an elegant solution to tertiary treatments due to the ability of microalgae to use inorganic nitrogen and phosphorus for their growth and also, for their capacity to remove heavy metals, as well as some toxic organic compounds, in the current review we highlighted the role of micro-algae in the treatment of wastewater and growth parameters to be affected for the cultivation. The treatment of different types of wastewater by physicochemical or biological (non-microalgal) methods could often be either inefficient or energy-intensive. Microalgae are ubiquitous microscopic organisms, which thrive in water bodies that contain the necessary nutrients. Wastewaters are typically contaminated with nitrogen, phosphorus, and other trace elements, which microalgae require for their cell growth. In addition, most of the microalgae are photosynthetic in nature, and these organisms do not require an organic source for their proliferation, although some strains could utilize organics both in the presence and absence of light. Therefore, microalgal bioremediation could be integrated with existing treatment methods or adopted as the single biological method for efficiently treating wastewater. This review paper summarized the mechanisms of pollutants removal by algae, microalgal bioremediation potential of different types of wastewaters, the potential application of wastewater-grown microalgal biomass, existing challenges, and the future direction of algae application in wastewater treatment.
Keywords-Wastewater Treatment, Algae, BOD, COD

I. INTRODUCTION

The introduction of organic and inorganic substances to the environment is a result of human activities such as agriculture, domestic and industrial wastewater which leads to pollution. Treatment processes of these wastewaters are being conducted globally to eliminate easily settled materials and recover nutrients in an attempt to release clear and apparently clean effluent into natural waters. Lack of removing inorganic nitrogen and phosphorus nutrients is the greatest cause of eutrophication in water bodies which inhibits the life of other organisms as well as pose a threat to human life and loss of the economy. Different technologies have been applied and are being developed to recover nutrients as well as heavy metals from wastewater to meet the permissible limits before discharging effluents. Wastewater treatment using microalgae offers an opportunity to provide tertiary bio-treatment and production of valuable biomass[1].Algae use the available inorganic nitrogen and phosphorus for their growth which are then harvested for various uses. Additionally, they have the ability to remove heavy metals and some toxic compounds.

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Among many conventional processes available for wastewater treatment inverse fluidisation process which is a three phase fluidisation process has been widely used for many applications such as hydro-treating and conversion of heavy petroleum and synthetic, crystaliization, food processing, biomedical engineering, methanol production, treatment of municipal sewage wastewater and similarly many processes. Some of the benefits which one's process can gain if this unit is used are easy to handle, less consumption of power, low space requirement, less chemical waste and eco-friendly as it does not produce any chemical as its waste after the process. Indeed the most significant feature of it is high efficiency as compared to the other conventional fluidization processes[2]. The name inverse fluidisation comes from the direction of flow of liquid and gas which depends upon the density of the particle. Here the liquid is fed continuously from the top using pump if it is a continuous process and gas is released from using sparger form the bottom after it has been compressed in a compressor, thus it makes the process counter current flow process. In this counter current flow process the density of the particle is lesser than that of the liquid which is in a continuous phase[3]. With the rapid growth in population and industrialization is leading to the depletion of natural resources and causing major environmental problems such water pollution, soil pollution etc. The environmental problem which is of our concern is water pollution which is mainly caused due to the discharge of heavy metals from steel ,dairy and fertilizer industries and nitrogen ,phosphorus, sulphides and chlorides[4] . Due to rapid use of nitrogen in fertilizer industries an excessive amount of it may cause several health related problems and causes eutrophication and acidification of water bodies. To overcome this process there are various methods which have been used for decades but the question arises is which process is more economical and numerous benefits over others.Algae involves process which is very similar to the green plants and the most common process in plant is photosynthesis. Algae absorbs sunlight which is a source of carbon dioxide for it and convert it into oxygen and photosynthesis takes place through chlorophyll present in it. Algae size varies from single cell to branched size of visible length[5]. Some of the algae which grow in waste water are chlorella sp., Spirulina sp., Microactinium sp., and some more. The treatment of wastewater can be achieved by biodegradation of it using bacteria or algae. Biodegradation converts organic matter into smaller molecules which requires oxygen for the process. And supply of oxygen is tedious and costly. Thus it is better to use natural abundance source of oxygen which can give lot of benefits apart from biodegradation[6]. Algae absorbs various compounds and nutrients such as nitrogen, phosphorus and metals required for its growth. Some of the benefits which is prominent in today's century are reduction in green -house -gases and production of useful products from end product which is a highly rich nutrient containing algae itself and can further be used for production of biofuel and diet supplementary. Aeration is an energy intensive process and accounts for 45-70 % of total energy cost of treatment plant. Algae consumes CO_2 in a larger amount than it is released during the process. Chlorella Scenedesmus is one among the fastest growing genus of single celled green algae, includes 14%-22% of lipid, 51%-58% of protein, 12%-17% of carbohydrates, and 4%-5% of nucleic acid.

II. BIOLOGICAL OXYGEN DEMAND (BOD) AND CHEMICAL OXYGEN DEMAND(COD)

COD test is used to measure the amount of organic compounds in water in other words we can say that it is the amount of oxygen required to chemical oxidize the pollutants. The applicable range of COD is 3-900 mg/ml. BOD test is used to determine the amount of oxygen required by the microorganism to break the organic material present in the sample at a particular temperature over a specific period of time. Generally the time taken for test is 5days at a temperature of 20 degree Centigrade. It is also a principle test which predicts the biodegradability of any water or wastewater sample. The efficiency of wastewater is measured by measuring the effluent BOD and influent BOD of the sample taken. Any effluent to be discharged into the water should have BOD less than 30mg/ml. COD value is always greater than BOD value[7] .It is found from the research that the COD values for domestic and industrial wastewater is about 2.5 times the BOD value. The ratio of BOD to COD if greater than 0.8 then it is considered that the water is highly polluted and amenable to biological treatment.

III. LITERATURE REVIEW

Chan et al in 2013 Heavy metal uptake by three types of algae Chlorella sp., Spirulina sp., and other algae found in wastewaters of industries. They used untreated and autoclaved effluents as a substrate and observed that microalgae removed up to 81.7% of copper and 94.1 % of zinc and also found that higher heavy metal removal is obtained in autoclaved effluents because the presence of microbes in untreated effluents put negative impact on the removal efficiency. Deviram et al in 2011 used the microbial mats for the study using different species of algae such as Ulva sp., Cladophora sp. and Chlorella sp. and observed COD and BOD in three different types of process free cell process, batch process and continuous process and found that better results were developed in continuous process with 52.1(COD) and 50.8(BOD) along with changes in dissolved oxygen (DO) and pH.Kim et al. in 2010 studied the capability of Chlorella vulgaris to remove nitrogen in the form of ammonia and ammonium ion from local wastewater.

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The wastewater effluent leaving the plant was found to include high concentrations of nitrogen (7.7± 0.19 mg/L) (ammonia (NH_3) and ammonium ion (NH4+)) and total inorganic carbon (58.6±0.28 mg/L) at pH 7, and to be suitable for growing Chlorella vulgaris. When Chlorella vulgaris was cultivatedin a batch mode under a closed system, half of the nitrogen concentration was dramatically removed in 48 h after a 24h lag-phase period. Researchers have been considering algae for wastewater treatment for quite some time. William J. Oswald was one of the first researchers to propose this in the 1950s. Algae benefit wastewater treatment by producing oxygen that allows aerobic bacteria to breakdown organic contaminants in the water and taking up excess nitrogen and phosphorus in the process. It is also a sustainable and affordable alternative to current wastewater treatment practices. What's new in this field today is our use of a different type of algae from Yellowstone National Park that likes high temperatures and is very stable and low pH values-about the same pH levels as Coca Cola. Pathogens (biological agents that causes disease) die pretty rapidly under those conditions. Therefore, wastewater treated by this method would require less chemical disinfectant. This platform represents a new paradigm in the use of algae for wastewater treatment.

IV. REDUCTION OF BOTH CHEMICAL AND BIOCHEMICAL OXYGEN DEMAND

There are many compounds and microorganisms could be detected in wastewater, which is capable of causing the pollution of a water-course. Pollution of wastewater may be manifested in three broad categories, namely organic materials, inorganic materials in addition to microbial contents. The organic compounds of wastewater comprise a large number of compounds, which all have at least one carbon atom[8]. These carbon atoms may be oxidized both chemically and biologically to yield carbon dioxide. If biological oxidation is employed the test is termed the Biochemical Oxygen Demand (BOD), whereas for chemical oxidation, the test is termed Chemical Oxygen Demand (COD). In other words, BOD exploits the ability of microorganisms to oxidise organic material to carbon dioxide and water using molecular oxygen as an oxidizing agent. Therefore, biochemical oxygen demand is a measure of the respiratory demand of bacteria metabolizing the organic matter present in wastewater[9]. Excess BOD can deplete the dissolved oxygen of receiving water leading to fish kills and anaerobiosis, hence its removal is a primary aim of wastewater treatment. Colak and Kaya (1988) investigated the possibilities of biological wastewater treatment by algae. They found that, in domestic wastewater treatment, elimination of BOD and COD were 68.4% and 67.2%, respectively Removal of N and/or P The bio-treatment of wastewater with algae to remove nutrients such as nitrogen and phosphorus and to provide oxygen for aerobic bacteria was proposed over 50 years ago by Oswald and Gotaas (1957). Since then there have been numerous laboratory and pilot studies of this process and several sewage treatment plants using various versions of this systems have been constructed (Shelef et al., 1980; Oswald, 1988a,b; Shi et al., 2007; Zhu et al., 2008). The nitrogen in sewage effluent arises primarily from metabolic interconversions of extra-derived compounds, whereas 50% or more of phosphorus arises from synthetic detergents. Together these two elements are known as nutrients and their removal is known as nutrient stripping (Horan, 1990). Wastewater is mainly treated by aerobic or anaerobic biological degradation; however, the treated water still contains inorganic compounds such as nitrate, ammonium and phosphate ions, which leads to eutrophication in lakes and cause harmful microalgal blooms (Sawayama et al., 1998). Prased (1982) and Geddes (1984) have considered P and N to be the key of eutrophication. So, further treatment is thus necessary to prevent eutrophication of water environment (Sawayama et al., 2000). The adverse effects of nutrient enrichment in receiving sensitive bodies of water can cause eutrophication by stimulating the growth of unwanted plants such as algae and aquatic macrophytes. Other consequences of nitrogen compounds in wastewater effluents are toxicity of non-ionized ammonia to fish and other aquatic organisms, interference with disinfection where a free chlorine residual is required and methemoglobinemia in influents due to excessive nitrate concentrations (above 45 g m3) in drinking water (Lincolin and Earle, 1990) . Microalgal culture offers a cost-effective approach to removing nutrients from wastewater (tertiary wastewater treatment) (Evonne and Tang, 1997). Microalgae have a high capacity for inorganic nutrient uptake (Talbot and De la Nou¨e, 1993; Blier et al., 1995) and they can be grown in mass culture in outdoor solar bio-reactors (De la Nou¨e et al., 1992). Biological processes appear to perform well compared to the chemical and physical processes, which are in general, too costly to be implemented in most places and which may lead to secondary pollution (De la Nou¨e et al., 1992). Microalgal cultures offer an elegant solution to tertiary and quaternary treatments due to the ability of microalgae to use inorganic nitrogen and phosphorous for their growth (Oswald, 1988b,c; Richmond, 1986) and their capacity to remove heavy metals (Rai et al., 1981). Lau et al. (1996) studied the ability of522 Chlorella vulgaris in nutrients removal and reported a nutrient removal efficiency of 86% for inorganic N and 78% for inorganic P. In earlier study, Colak and Kaya (1988) reported an elimination of nitrogen (50.2%) and phosphorus (85.7%) in industrial wastewater treatment and elimination of phosphorus (97.8%) in domestic wastewater treated by algae. In reported papers, Lau et al. (1996) studied the ability of Chlorella vulgaris in the removal of nutrients. They found that the results indicated in a nutrient removal efficiency of 86% inorganic N and 70% inorganic P.

In earlier study, Colak and Kaya (1988) reported an elimination of nitrogen (50.2%) and phosphorus (85.7%) in industrial wastewater treatment and elimination of phosphorus (97.8%) in domestic wastewater treated by algae. The interest in microalgal cultures stems from the fact that conventional treatment processes suffer from some important disadvantages: (a) variable efficiency depending upon the nutrient to be removed; (b) costly to operate; (c) the chemical processes often lead to secondary pollution; and (d) loss of valuable potential nutrients (N, P) (De la Nou¨e et al., 1992). The last disadvantage is especially serious, because conventional treatment processes lead to incomplete utilization of natural resources (Guterstan and Todd, 1990; Phang, 1990). Many studies demonstrated the success of using algal cultures to remove nutrients from wastewater rich in nitrogenous and phosphorus compounds (Przytocka-Jusiak et al., 1984; Rodrigues and Oliveira, 1987). Mohamed (1994) pointed out that Scenedesmus sp. is very common in all kinds of fresh water bodies, which play an important role as primary producers and contributes to the purification of eutrophic waters. The author indicated that the presence or absence of certain species of Scenedesmus can be used for the evaluation of water quality. To avoid recycling of nutrients in receiving waters, and to recover the biomass produced, harvesting or physical recovery of the algal cells is also essential, and represents one of the important technical and economic difficulties to overcome (Benemann, 1989). Indeed, most of the experiments carried out until now have used planktonic and unicellular microalgal species which are difficult to harvest (Mohn, 1980; De la Nou¨e and De Pauw, 1988). Removal of inorganic compounds by using plants or microalgae has advantages of renewability and utilization of solar energy (Sawayama et al., 1998). Under suitable conditions, cyanobacteria can grow at higher rates than higher plants (Watanabe and Hall, 1996), so that inorganic nutrientsremoval systems using cyanobacteria appear to have a considerable potential (Sawayama et al., 1998). With the increasing use of inorganic nitrogenous fertilizers and the production of wastes from human and animal populations, there are signs of nitrogen (N) accumulation in the environment, in the case of N pollution, most concern stems from the possible health hazards that have been attributed to nitrite either directly as a causative factor of methemoglobinemia or indirectly as the source of nitrosamines (Tam and Wong, 1989). Also, nitrites themselves are important as precursors of N-nitroso compounds, mainly nitrosamines, which have received considerable attention due to their possible carcinogenic, teratogenic and mutagenic properties (Abel, 1989). Since nitrate is not significantly removed by conventional water treatment, much research is focused on the development of new techniques for reducing nitrates in drinking water to tolerable levels.

V. ALGAL CULTIVATION IN DIFFERENT WASTEWATERS

Typical micro-algal biomass concentration in large scale open cultivation could be 0.5 g/L. Depending on the cellular composition of the microalgae, nitrogen, and phosphorus content in the biomass could be in the range of 5.4-8.7% and 0.7-1.1%, respectively. Therefore, microalgae alone could potentially consume or remove 43.5 and 5.5 mg/L of nitrogen and phosphorus, respectively, from wastewater. Additionally, microalgae could also adsorb pollutants from wastewater and assist other microorganisms in removing additional contaminants. Considering wastewater would have all other necessary microelements. In case wastewater contains excessive TN and TP, then such wastewater needs to be diluted to an appropriate ratio before micro-algal bioremediation[10].

A. Municipal Wastewater

Typical nitrogen and phosphorus concentrations in the municipal sewage wastewater (MSWW) are 21.9-28.8 and 8.2-10.4 mg/L. The concentration of dissolved organics in the MSWW is usually low for the bacteria for the complete consumption of nitrogen and phosphorus. Hence, after the activated sludge process (ASP), an advanced treatment process is adopted to remove excess nutrients (N, P). Microalgae could remove the residual nitrogen and phosphorus from the effluent of ASP[11]. However, microalgae cultivation in the MSWW could efficiently remove nitrogen, phosphorus, BOD, and heavy metals. Microalgae could also remove pathogens from the MSWW.

B. Industrial Wastewater

For several countries, the textile industry wastewater (TWW) could contribute more than 10% (as high as 30%) of the total industrial wastewater. TWW often contains dyes, fats, acids, binders, salts, heavy metals (e.g., Cr, Cu, As, Zn, etc.), thickeners, and reducing agents, in addition to nitrogen and phosphorus compounds. The dyes in the TWW are recalcitrant organics and pose a challenge in its remediation and simultaneously could adversely affect the quality of the receiving water bodies, even at low concentrations. A number of physicochemical techniques were studied to treat TWW; however, most of these methods could be costly, energy-intensive, and inefficient. Bioremediation of TWW by different microorganisms (i.e., yeast, bacteria, microalgae) was explored. Microalgae were able to utilize several dyes (e.g., EriochromeblueSE and blackT) as a source of carbon and nitrogen.

While microalgae could consume the organic compounds of TWW, the organic dyes in the TWW could also be adsorbed on to the microalgal cells, thereby treating the TWW. Produced Water Produced waters from oil and gas industries contain toxic petroleum compounds, in addition to various heavy metals and added chemicals (i.e., hydrocarbons, volatile fatty acids, carbonyl group, and high molecular weight organic acids). While the produced water could be toxic to many micro-algal strains, some algal strains (e.g., Chlorella sp., Dunaliella sp., Scenedesmus sp., etc.) could tolerate and grow in the produced or pre-treated produced water. The algae-bacterial consortium could effectively treat the produced water. The feasibility of large-scale micro-algal biomass production in several countries, using produced water, was recently explored. The Aqueous Phase of Biomass to Energy Generation Process The digestate of the anaerobic process often contains very high concentrations of TN, TP, and other elements; this digestate could be a source of nutrients for microalgal cultivation. In recent times, hydrothermal liquefaction (HTL) technology is being studied as a promising technology for converting various biomass into biocrude oil.

C. Pharmaceuticals Wastewater

Wastewater contaminated with pharmaceuticals and personal care compounds (PPCCs) poses a serious threat because of their ecotoxicity and health issues. Some of these PPCCs could not be efficiently removed by the existing activated sludge process. On the contrary, microalgae have the ability to remove the PPCCs such as triclosan from wastewater, although the efficiency of removal would vary among microalgal strains and operating conditions. Microalgal removal of PPCCs from wastewater could occur in three potential pathways: adsorption, accumulation, and degradation, either intracellular or extracellular[12]. Microalgae could also be used as indicators/markers to assess the toxicity of some PPCCs derivatives like triclosan in wastewater discharges and natural water bodies. Microalgal adsorption efficiency for PPCCs are rather low 0–16.7%. A few microalgae could uptake and accumulate several PPCCs, such as organic substrates and separate from the contaminated water. Some of the microalgae showed a limited ability to degrade several PPCCs; however, in the presence of a suitable organic compound, the degradation rate and efficiency greatly increased. Although microalgal removal of a couple of PPCCs (e.g., benzothiazole, diclofenac, OH-Benzothiazole, etc.) were affected by seasonal variation (temperature), the removal of most common PPCCs (e.g., caffeine, acetaminophen, ibuprofen, etc.) in wastewater was minimally affected by the variation in temperature. However, as the microalgal cell gets exposure to the PPCCs, its metabolites composition needs to be characterized. Further, transformation products of these PPCCs into other products need to be identified and characterized.

D. Agro-Industry Wastewater

Wastewater generated from livestock (piggery, cattle) and poultry industries are typically rich in nitrogen and phosphorus; microalgae were used to successfully recover nutrients and produce biomass while treating wastewaters from these industries. Dairy industries wastewater is generally rich in organic content with high BOD_5 and COD values; therefore, mixotrophicmicroalgal strains could be very efficient in treating DWW. Microalgae were also used to treat wastewater from the carpet mill, brewery effluents. Similarly, microalgae were able to treat wastewater generated from food processing industries. Wastewater Derived from Mining Activity Wastewaters from mines are typically acidic in nature and could contain potentially hazardous metals; because of micro-algal ability to intra and/or extra cellular accumulation of various metals, these organisms could potentially be applied to treat mine wastewater, mainly both inside and outside the cell.

E. Landfill Leachate

Landfill leachate often contains a high concentration of ammonia that itself could be toxic to microalgae. Additionally, the leachate's black-colour could interfere with the light penetration and, consequently, micro-algal growth and remediation of leachate. An appropriate dilution or pretreatment would be required for the efficient treatment of the leachate. Raw leachate could be mixed with seawater or pre-treated leachate for micro-algal bioremediation. It was demonstrated that a consortium of five microalgae could efficiently remove COD, NH3-N, and orthophosphate from aerobically treated leachate in high rate algal ponds (HRAP). At times, phosphorus concentration in the leachate could be low, and it should be supplemented as an appropriate concentration since microalgae require phosphorus for their growth.

F. Aquaculture Wastewater

For the intensive aquaculture system, the effluent often contains an elevated concentration of dissolved nitrogen compounds, mainly in ammonia, generated from the undigested feed and the feces. While bacterial nitrification of ammonia and other nitrogenous compounds to gaseous nitrogen is a feasible option, micro-algal assimilation of these nitrogenous compounds could be a sustainable alternative option, as the produced biomass could be used as superior feed ingredients.

In another study, micro-algal-bacterial floc was applied in a sequencing batch reactor to successfully treat the aquaculture wastewater; the easy separation of micro-algal-bacterial floc by gravity sedimentation could reduce the overall cost of aquaculture wastewater treatment

VI. CHALLENGES OF MICRO-ALGAL WASTEWATER TREATMENT AND FUTURE RESEARCH DIRECTION

In large-scale outdoor microalgal cultivation, the average biomass productivity could range from 15-30 g/m^2/day. Considering microalgal cellular nitrogen content around 4-6%, microalgal nitrogen uptake rate could be in the range of 0.6-1.8 g N/m^2/day. Therefore, for a 20 cm deep pond, the nitrogen removal rate would be 3.0-9 mg N/L/day. On the contrary, the nitrogen removal rate in a typical activated sludge process is around 30-78 mg N/L/day, several times higher than the micro-algal nitrogen removal rate. Therefore, a larger footprint would be required for the micro-algal bioremediation of wastewater. The other concern of micro-algal bioremediation is the seasonal variability of light intensity and temperature. Unlike bacteria, microalgae would require sunlight for their cell growth; cloud covers and shorter daylight during the winter season would limit the rate of micro-algal bioremediation. Metabolic engineering pathways for several microorganisms (e.g., yeasts and bacteria) are already well established, and these microorganisms could be tailored for specific purposes. However, more research in micro-algal metabolic engineering would be needed to overcome some of the challenges of micro-algal bioremediation of wastewater. Microalgae biomass growth rate, nutrient recycling, and wastewater treatment efficiencies would be limited in the absence of an external CO_2 supply. A point source of CO_2 (e.g., flue gas) in the vicinity of the cultivation site would enhance the overall process. Micro-algal biomass density for large scale open cultivation systems often does not exceed 0.5 g/L, which could be mainly attributed to the light saturation at the top layer. Keeping a deeper culture would result in reduced biomass density. Although higher flow velocity could improve the mixing and light utilization, the increment in energy requirement for increased flow velocity follows the cube law of power. Therefore, the culture depth and flow velocity must be optimized for biomass production in large-scale cultivation. Although a microalga could have very high efficiency in removing specific contaminant, its sudden exposure to wastewater containing a very high concentration of that contaminant (e.g., metals, toxic compounds) could be detrimental to its culture, which in turn could undermine the effectiveness of the treatment process. Therefore, an adaptation or climatization process for the strain to the target compound(s) needs to be developed on site. At times, wastewater could have a very high concentration of ammonia, which could be toxic to many micro-algal strains. In some wastewaters, nitrogen could be present inaromatic compounds as nitro, amino, or other groups. If the pH value of wastewater is either very low or very high, then it should be adjusted in the appropriate range for efficient micro-algal bioremediation. The concentration of nitrogen and or phosphorus in wastewater could be low in wastewater, which would yield a low biomass density; the cost and energy requirement per unit of biomass separation could be very high-rendering the overall process of micro-algal bioremediation nonviable. The ability of a single microorganism to completely degrade an aromatic or a mixture of xenobiotic pollutants is rarely observed. To achieve a better removal efficiency for such unwanted contaminants from wastewater, the combination of microalgae and other suitable microorganisms could be applied. Although polycultures of microalgae could have better efficiency in treating wastewater compared to the bioremediation efficiency of monoculture, over the long term, the consistency in polyculture biomass quality could be a concern. If bio-flocculation is used to harvest any desired microalga, the bio-flocculating strain could impair the quality of the overall biomass. Depending on the climate condition, the evaporation water loss could be 0.1–2 cm per day from an open cultivation system. The evaporation water loss could increase the concentrations of pollutants in the culture, which would ultimately affect the bioremediation efficiency. The treated wastewater from the previous batch could be used, as necessary, to compensate for the evaporation water loss. Despite the immense potential of micro-algal bioremediation of wastewater and the successful demonstration mostly at a relatively small scale (primarily indoor), long-term, large-scale demonstrations are limited. The effect of annual variations in light and temperature on the bioremediation efficiency and microalgal biomass quality needs to be studied. If coagulants or cross-flow filtration are used to separate microalgae biomass, it will increase the overall cost of bioremediation. Attached cell growth could eliminate the step for biomass harvesting; however, the cost of preparing the immobilization matrix could be extremely high. Hence, appropriate strain or growth conditions should be used that facilitate autoflocculation or bioflocculation of the biomass. Unlike heterotrophic microorganisms, most of the microalgae would require carbon dioxide for their growth and biomass production. Although wastewaters typically contain nitrogen, phosphorus, and some other elements, as required by microalgae, supplying CO_2 to the microalgae culture is very crucial for effective treatment of wastewater, as the diffusion of atmospheric CO_2 into the microalgae culture is usually very slow and low. Coupling the flue gas, as the source of CO_2, into the cultivation of microalgae in wastewater could enhance the environmental sustainability of the industry.

Although the microalgal commercial application is mostly limited to the cultivation of microalgae in freshwater or seawater as food, feed, and nutraceuticals, there is a need to develop novel and wider applications of wastewater-grown microalgal biomass. In the context of a circular bio-economy, the bioremediation of wastewater by microalgae and the complete valorization of the produced biomass could be very promising. Earlier research efforts were mostly dedicated to microalgal bioremediation or the generation of value-added products from wastewater-grown microalgae biomass. Suitable applications should also be developed for the residual biomass after extracting or converting a fraction of the biomass

VII. CONCLUSION

COD and BOD analysis of wastewater is one of the basic step which is needed to set up any wastewater treatment plant and to control losses to the sewer system. Many ways of chemical treating wastewater has been proved to be very expensive and produces harmful end product which is very necessary to be avoided in today's century. This study which includes treatment of steel plant waste water with the most abundantly available resource i.e., algae shows a new pathway to achieve two major goals of any wastewater treatment plant first being the economy and second being the efficiency in reduction of harmful components present in industrial , domestic or municipal wastewater. The role of individual microorganisms in microalgae-bacterial or microalga-microalgae consortia needs a better understanding of the long-term outdoor operation. The development of a strain and application-specific energy-saving biomass harvesting is a prerequisite for microalgal bioremediation of wastewater; in this regard, a self-settling strain or bioflocculating strain consortia should be developed. Furthermore, the harvested microalgal biomass needs to be valorized, in a multi-product biorefinery approach, to enhance the economic viability and environmental sustainability of wastewater bioremediation. It's easy to associate algae as being a nuisance. Microalgae are single-cell algae species that can survive individually or in clusters. They are among the most important groups of organisms on the planet because they produce approximately half of the atmospheric oxygen on earth, while also consuming vast amounts of greenhouse gas carbon dioxide. Algae can be used in wastewater treatment for a range of purposes, including reduction of BOD, removal of N and/or P, inhibition of coliforms, removal of heavy metals. The high concentration of N and P in most wastewaters also means these wastewaters may possibly be used as cheap nutrient sources for algal biomass production. This algal biomass could be used for: methane production, composting, production of liquid fuels (pseudo-vegetable fuels),as animal feed or in aquaculture and production of fine chemicals.

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