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Production of Biofertilizer from Industrial Waste Water by Microalgal Treatment

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Abstract: *Due to rapid industrialization and the depletion of non-renewable fossil fuels, alternative feasible renewable alternatives are being sought to supply rising energy demand while reducing carbon dioxide emissions. Microalgae cultivation has the to meet these criteria in today's world energy strategy, which is centred on cost-effective and environmentally friendly alternatives. Microalgae has been discovered as a promising and long-term solution for wastewater treatment and the generation of valuable products. Microalgae, which have a short life cycle, a rapid growth rate, and a high CO2 usage efficiency, are one of the most feasible renewable resource technologies for producing biomass from wastewater nutrients. Technology and cost are now the key issues limiting industrial-scale use, which necessitates an optimum downstream process to reduce manufacturing costs. These issues have become feasible and economically viable thanks to the utilisation of microalgae for wastewater treatment and biofuel generation at the same time. The efficacy of microalgae for the removal of ammonia, phosphorus, and heavy metals, as well as the creation of biofuel and biofertilizer, is examined. It also aims to concentrate on current breakthroughs in wastewater microalgae growth, as well as the response of microalgae to various stimuli and their implications on the quality and quantity of high-value products.*

Keywords: Waste Water, Treatment Methods, Nutrients, Bio Fertilizer, Environment, Effluents, Microorganisms

I. INTRODUCTION

Wastewater is produced when fresh water is used in a number of applications, and it typically entails leaching, flushing, or washing away waste items and nutrients that have been introduced to the water during those uses. Used water from any combination of household, industrial, commercial, or agricultural activity, surface runoff / storm water, and any sewer inflow or sewer infiltration, according to a more thorough definition of wastewater. Wastewater is sometimes used interchangeably with sewage (also known as sewerage, household wastewater, or municipal wastewater), which is wastewater generated by a group of people. It is usually disposed of in a sewage system[1].To avoid eutrophication, liquid wastewater streams containing nitrogen must be treated before being released into the environment. There are already a number of conventional treatment systems that can remove nitrogen from wastewater using a mix of procedures. A portion of nitrogen will be released into the atmosphere, depending on the processes involved. Several species of microalgae, on the other hand, have a voracious appetite for nitrogen and can absorb waste-bound nitrogen in a single step, primarily as intrinsic proteins. The minerals inside the microalgae cells remain available for plants once they are isolated from the water, and they may be utilised as fertiliser. Microalgae may grow in wastewater and extract nutrients; this wastewater-grown biomass can be utilised as a biofertilizer for crops. Furthermore, by removing microalgal biomass from the wastewater at the conclusion of the process, the waste water can be treated fully, or at least partially, reducing the time and expense of traditional treatment. Qatar's climate and lack of arable land make it perfect for growing microalgae[2].

II. WASTE WATER

Water that has been contaminated by home, industrial, or commercial use is referred to as wastewater. As a result, the composition of all wastewaters is always changing and extremely variable. The makeup of wastewater is 99.9% water, with the remaining 0.1 percent being removed. Organic materials, bacteria, and inorganic chemicals make up the 0.1 percent. Wastewater effluents are discharged into lakes, ponds, streams, rivers, estuaries, and seas, among other places. Storm runoff

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comprises dangerous elements that wash off roadways, parking lots, and rooftops. Human excrement, protein, fat, vegetable, and sugar material from meal preparation, as well as soaps, make up the organic composition of wastewater. Some of this organic matter dissolves in water, while others remain as distinct particles. Suspended solids are the parts of organic material that do not dissolve but stay suspended in water. The organic material in wastewater is removed as much as possible. Sodium, copper, lead, and zinc, among other inorganic minerals, metals, and compounds, are abundant in sewage and wastewater. They can come from a variety of places, including industrial and commercial facilities, rainwater, and inflow and infiltration through damaged pipes. The majority of inorganic compounds are stable and cannot be easily broken down by bacteria in waste water. Eutrophication is caused by excess nutrients such as phosphorus and nitrogen, which can be hazardous to aquatic creatures. This also encourages excessive plant growth and lowers oxygen availability, changing ecosystems and perhaps putting certain species at risk[3].

2.1. Waste Water Classification

A. Industrial Waste Water

These waters are created by various industrial operations and include any unit operation's undesirable liquid result. The main worry with these wastes is the potential for direct or indirect interactions with the environment. Some may deplete the environment's oxygen supply, while others may be poisonous. Industrial Water Pollutants from industry that run off into streams, rivers, or lakes can harm wildlife, plants, and humans. The amount and type of pollutants that industries can discharge into bodies of water are strictly regulated in the United States. These regulations aren't always followed, and chemical and oil accidents are a major source of industrial water contamination. Depending on the sort of company that produces it, industrial wastewater has a wide range of quality and volume. It could be extremely biodegradable or not, and it could contain or not contain components that are resistant to treatment. Organic synthetic chemicals or heavy metals, for example, whose content in developing country wastewater may differ significantly (in quantity and quality) from that in developed countries. The main source of worry with industrial wastewater is the growing amount (in terms of both quantity and variety) of synthetic substances included in and discharged to the environment[4].Wastewater is produced by almost every industry. The recent trend has been to reduce such production or recycle treated wastewater in the manufacturing process. Some industries have been successful in reducing or eliminating pollutants by restructuring their manufacturing processes. Battery manufacturing, chemical manufacturing, electric power plants, food processing, iron and steel industry, metal working, mines and quarries, nuclear power plants, oil and gas extraction, petroleum refining and petrochemicals, pharmaceutical manufacturing, pulp and paper industry, smelters, textile mills, industrial oil contamination, water treatment, and wood preservation are all sources of industrial wastewater[5].

B. Domestic Waste Water

Domestic wastewater has a grey colour, a musty odour, and a solids concentration of roughly 0.1 percent on a physical level. Faeces, food particles, toilet paper, grease, oil, soap, salts, metals, detergents, sand, and grit make up the solid stuff. The solids can be dissolved as well as suspended (approximately 30%). (about 70 percent). Chemical and biological processes can precipitate dissolved solids. When suspended materials are discharged into the receiving environment, they might result in the formation of sludge deposits and anaerobic conditions.

In terms of chemistry, wastewater is made up of organic (70%) and inorganic (30%) components, as well as different gases. Carbohydrates (25 percent), proteins (65 percent), and fats (10 percent) make up the majority of organic molecules, which reflects people's diets. Heavy metals, nitrogen, phosphorus, pH, sulphur, chlorides, alkalinity, hazardous chemicals, and other inorganic components may be present. However, because wastewater has a higher percentage of dissolved solids than suspended solids, approximately 85 to 90% of the entire inorganic component is dissolved, whereas approximately 55 to 60% of the total organic component is dissolved. Hydrogen sulphide, methane, ammonia, oxygen, carbon dioxide, and nitrogen are all gases that are regularly dissolved in wastewater. The degradation of organic materials in the wastewater produces the first three gases.

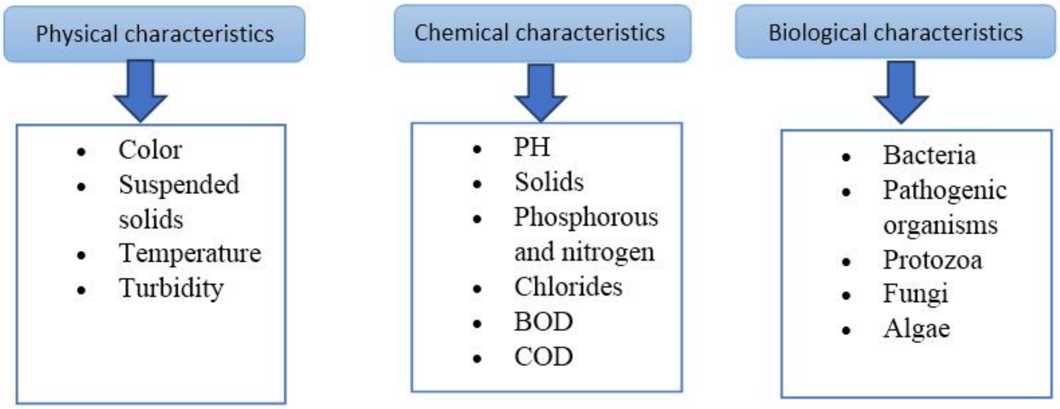
Biologically, wastewater comprises a wide range of microbes, but those classed as protista, plants, and animals are of particular significance. Bacteria, fungus, protozoa, and algae are all classified as Protista. Ferns, mosses, seed plants, and liverworts are examples of plants. The animal category includes both invertebrates and vertebrates. Protista, particularly bacteria, algae, and protozoa, are the most important category in wastewater treatment. In addition, wastewater contains a large number of pathogenic organisms, most of which come from individuals who have been affected with a disease or who are carriers of a disease. Typical faecal coliform concentrations in raw wastewater range from several hundred thousand to tens of millions per 100 ml of sample[6].

C. Storm Waste Water

Stormwater, usually called storm water, is water that comes from extreme precipitation (storm), such as heavy rain and hail and snow meltwater. Stormwater can penetrate into the soil and form groundwater, be held in ponds and puddles on depressed land surfaces, evaporate back into the atmosphere, or contribute to surface runoff. The majority of runoff is discharged untreated as surface water into neighbouring streams, rivers, or other big water bodies (wetlands, lakes, and oceans).Soil absorbs a lot of stormwater in natural settings like woods. Plants also help to reduce stormwater runoff by enhancing infiltration, intercepting rain as it falls, and absorbing water through their roots. Unmanaged stormwater in developed environments, such as cities, can cause two significant issues: one relating to the volume and timing of runoff (flooding), and the other related to potential toxins carried by the water (water pollution). In addition to the chemicals carried by stormwater runoff, urban runoff is now being recognised as a pollution source in and of itself. Stormwater has become a valuable resource as the human population and demand for water has increased, especially in arid and drought-prone areas. Stormwater collecting and purification techniques have the potential to make some metropolitan surroundings self-sufficient in terms of water[7].

2.2 Characteristics of Waste Water

Wastewater is classified based on its physical, chemical, and biological characteristics. Physical, chemical, and/or biological treatment will be used depending on the level of contaminants and local requirements. To get the best water quality, the three procedures are usually combined. The qualities of wastewater differ greatly depending on the industry. As a result, the treatment approaches to be employed to meet the compliance discharge criteria will be determined by the unique features. Because of the enormous number of contaminants, each substance's properties are rarely considered. Pollutant or characteristic classes are made up of materials that have comparable polluting impacts[8].



2.3. Waste Water Treatment

Wastewater treatment is the process of removing impurities from wastewater and converting it into effluent that may be recycled back into the water cycle. Once returned to the water cycle, the effluent has a low environmental impact or can be utilised for a variety of uses called water reclamation. A wastewater treatment facility is where the treatment takes place. Various types of wastewaters are treated by wastewater treatment plants of the proper type.The wastewater treatment process is divided into three stages: primary, secondary, and tertiary water treatment. More sophisticated treatment, known as quaternary water treatment, is necessary in some applications. This step deals with contamination levels of a few parts per million to billions of parts per billion, and it frequently includes oxidation or fine filtering. Each of these stages targets a different contaminant, and as the water progresses through the stages, it becomes cleaner[9].

A. Primary Treatment

Water is briefly stored in a settling tank during primary treatment, when heavier particles sink to the bottom and lighter solids float to the surface.

These components are kept back until they have settled, while the remaining liquid is released or transferred to the more stringent secondary phase of wastewater treatment. Mechanical scrapers at the tank's base continuously push collected sludge to a hopper, where it is pumped to sludge treatment facilities. Material that will float or settle out by gravity is removed during primary treatment. Screening, comminution, grit removal, and sedimentation are examples of physical processes. Long, closely spaced, narrow metal bars make up screens. They block floating waste like wood, rags, and other bulky materials from clogging pipes and pumps. The screens are cleaned mechanically in contemporary facilities, and the waste is quickly disposed of by burial on the plant grounds. To grind and shred debris that goes through the screens, a comminutor can be utilised. Later, sedimentation or flotation techniques are used to remove the shredded debris[10].

B. Secondary Treatment

Secondary wastewater treatment is meant to significantly degrade the biological component of the waste through aerobic biological processes, and it acts at a deeper level than primary treatment. Secondary wastewater treatment reduces common biodegradable pollutants to tolerable levels, allowing for safer discharge into the surrounding ecosystem. It can be done by biofiltration, aeration, Oxidation ponds. The soluble organic matter that escapes basic treatment is removed in secondary treatment. It also eliminates a higher percentage of suspended solids. Biological procedures are typically used to remove organic pollutants, with bacteria consuming them as food and converting them to carbon dioxide, water, and energy for their own growth and reproduction. The sewage treatment facility provides an appropriate environment for this natural biological process, albeit one made of steel and concrete. The removal of soluble organic matter at the treatment plant aids in the preservation of a receiving stream, river, or lake's dissolved oxygen balance[11].

C. Tertiary Treatment

The goal of tertiary wastewater treatment is to improve the water's quality to satisfy household and industrial standards, as well as to fulfil particular criteria for water discharge safety. In the case of municipally treated water, tertiary treatment also includes the elimination of pathogens, ensuring that the water is safe to consume. The final stage of the multi-stage wastewater treatment process is tertiary water treatment. Inorganic chemicals, bacteria, viruses, and parasites are all removed during the third stage of treatment. The treated water is safe to reuse, recycle, or discharge into the environment after these dangerous substances have been removed. In most cases, tertiary wastewater treatment entails final filtration of the treated effluent. It may be necessary to use alum to eliminate phosphorus particles from the water when necessary. Alum also causes any particulates that were not removed by primary and secondary wastewater treatment to clump together, allowing filters to extract them. The filters are backwashed as needed to remove the build-up of floc, allowing them to continue to function properly[12].

III. BIOFERTILIZER

A biofertilizer is a product that contains live microorganisms that colonise the rhizosphere or the inside of the plant when applied to seeds, plant surfaces, or soil, and encourage growth by increasing the supply or availability of primary nutrients to the host plant. [13].Biofertilizers supply nutrients to plants through natural processes such as nitrogen fixation, phosphorus solubilization, and the creation of growth-promoting chemicals. Biofertilizers contain microorganisms that restore the soil's natural nutrient cycle and increase soil organic matter. Healthy plants may be developed with the application of biofertilizers while also improving the soil's sustainability and health. Biofertilizers will likely minimise the need of synthetic fertilisers and pesticides, but they will not be able to completely replace them. Biofertilizers are organic agro-inputs that are "eco-friendly." Rhizobium, Azotobacter, Azospirilium, and blue green algae (BGA) have long been used as biofertilizers. Leguminous crops benefit from Rhizobium inoculant. Wheat, maize, mustard, cotton, potato, and other vegetable crops can all benefit from Azotobacter. Sorghum, millets, maize, sugarcane, and wheat are among the crops for which Azospirillum inoculations are advised. Nostoc or Anabaena or Tolypothrix or Aulosira, blue green algae belonging to the cyanobacteria genus, fix atmospheric nitrogen and are utilised as inoculants for paddy crops produced in both upland and lowland settings[14].

3.1. Types of Biofertilizer

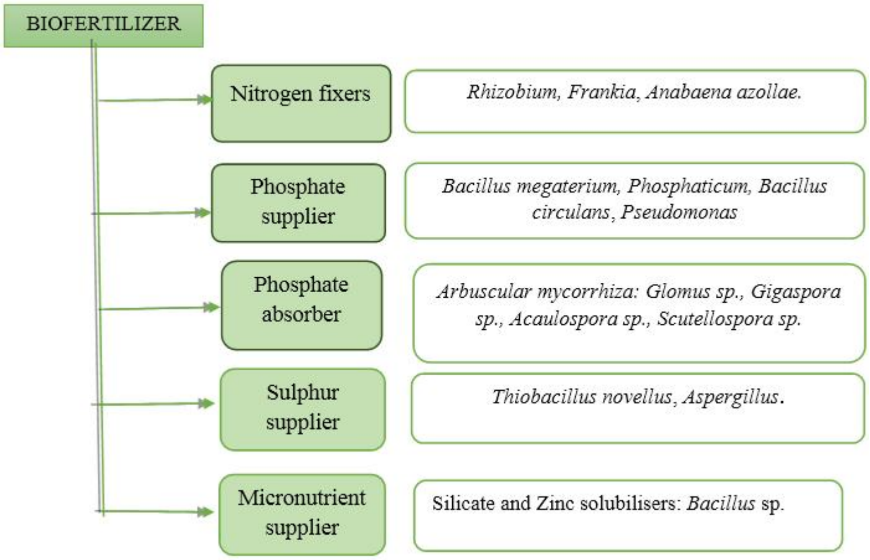
A. N_2 Fixing Biofertilizer:

Microorganisms including Rhizobium, Actinobacteria, Azotobacter, and Azospirillum are found in nitrogen-fixing biofertilizers. They aid in the conversion of nitrogen to organic molecules. One method of turning elemental nitrogen into a form that plants can use is biological nitrogen fixation. It is the process of converting nitrogen (N_2) to ammonia (NH_3). As a result of growing public awareness of water pollution and nitrate emissions, alternative sustainable sources such as nitrogen-fixing biofertilizers are becoming more important[15].

Biofertilizers that include nitrogen assist to balance nitrogen levels in the soil. Because plants require a particular quantity of nitrogen in the soil to flourish, nitrogen is a limiting element for plant development. Because various biofertilizers work best in different soils, the type of nitrogen biofertilizer to employ is determined by the farmed crop. Rhizobia is utilised in legume crops, Azotobacter or Azospirillum is used in non-legume crops, Acetobacter is used in sugarcane and blue-green algae, and Azolla is used in lowland rice fields[16].

B. Phosphate Solubilizing Biofertilizer

Phosphorus, like nitrogen, is a limiting element for plant growth. Phosphorus biofertilizers assist the soil in reaching its optimum phosphorus level and correcting phosphorus levels. Phosphorus biofertilizers, unlike nitrogen biofertilizers, are not dependent on the crops grown on the soil. Phosphatika is utilised in all Rhizobium, Azotobacter, Azospirillum, and Acetobacter-infected crop[17]. PSB is a phosphate biofertilizer that has been presented to the agricultural sector. Phosphorus (P) is one of the most important macronutrients for plants, and phosphate fertilisers are used to provide it to the soil. However, a considerable amount of soluble inorganic phosphate used as a chemical fertiliser in the soil is quickly immobilised and inaccessible to plants[18]. Currently, the primary goal of soil phosphorus management is to maximise crop yield while minimising P loss from soils. PSB have piqued agriculturists' interest as soil inoculums to boost plant growth and productivity. When PSB is used with rock phosphate, it can save up to 50% of the phosphatic fertiliser needed by the crop.Pseudomonas, Bacillus, Micrococcus, Aspergillus, Fusarium, etc. are the major phosphate solubilizing bacteria (PSB) in soil[19].



3.2. Biofertilizer Production

Waste waters are rich in nitrogen and phosphorus, and therefore have the potential to be used as low-cost microalgae medium. These organisms have the capacity to thrive in a wide range of settings and digest a wide range of nutrients. This type of biomass production is advantageous since the absorption of nitrogen and phosphorus from wastewaters can aid in the recycling of algal biomass as a biofertilizer while also reducing the usage of chemical fertilisers and sewage disposal[20].Microalgae may grow in wastewater and extract nutrients; this wastewater-grown biomass can be utilised as a biofertilizer for crops. India is one of the world's greatest producers and users of fertilisers, but the country's gradual growth in fertiliser usage has caused severe environmental issues, as well as being insufficient in light of present industrial capacity.The availability of macronutrients and micronutrients is a critical component in increasing crop yields[21]. The key important macronutrients in crop nutrition are nitrogen, phosphorus, and potassium. Because microalgal biomass contains more nitrogen and cyanobacterial members can fix atmospheric nitrogen, such microalgae/cyanobacteria can be used as biofertilizers in a variety of agricultural systems. Biofertilizers are micro/macroorganisms that can colonise the soil, rhizosphere, or plant interior to boost the plant's growth and nutrition[22].They also play a vital role in preventing soil erosion by controlling water flow into soils and promoting soil fertility, as well as in the reclamation of waste-lands, salty soils, and other arid environments. Microalgae boost the availability of soil nutrients to plants and function as plant growth promoters by releasing growth hormones. Certaincyanobacteria also help the plant develop by boosting its endogenous hormones[23]. The protein content of microalgal biomass is significant, and their multiplication need a lot of nitrogen as a fertiliser. However, the use of wastewater-grown biomass is debatable due to the accumulation of hazardous heavy metals, even if trace amounts might function as micronutrients, if present above acceptable limits. The presence of dangerous bacteria is a major downside of wastewater, however microalgal development is known to raise the pH of the media and restrict bacterial growth. This demonstrates that sewage-grown microalgae can provide a competitive advantage for the direct application of sewage sludge or wastewater in agricultural activities. Microbial biofertilizers are advantageous in cereal crops because they minimise the usage of chemical fertilisers while also improving the general health and nutritional state of the soil[24].

IV. MICROALGAE PRODUCTION AND HARVESTING

4.1. Production

A. Suspended Growth

In waste water, the most typical microalgae production method is a suspended growth system, which can be open or closed (photobioreactor or PBR). Biocoil, horizontal tubular, and vertical PBRs are the most commonly investigated PBRs for wastewater treatment[25]. Microalgae growing in the PBR has the potential to reduce or eliminate undesired pollution, evaporative water loss, and CO2 loss. Inside a PBR with a low optical depth, high volumetric biomass productivity can be achieved; as the optical depth of the PBR increases, the biomass productivity decreases[26]. In general, the cost of PBR materials for wastewater treatment may be excessively expensive. Furthermore, the energy required to mix the culture inside a PBR may be several times greater than the calorific energy of the microalgal biomass generated. Despite various obstacles (evaporation water loss, pollution, etc.), open growing of microalgae in wastewater could be highly promising[27]. Earthen lagoons, concrete tanks, and raceway ponds were used to investigate microalgal bioremediation of wastewater. The open type cultivation systems, such as the high rate algal pond (HRAP) and the corrugated raceway pond (CRP), were specifically intended for treating wastewater. The depth of the open cultivation system could vary from 0.15–0.45 m because microalgae are good at absorbing light, the top layer of the culture would absorb the majority of it, leaving the cells below in the dark[28]. Microalgal culture mixing in a large-scale open system is frequently insufficient, hence microalgal bioremediation in a deeper pond may be ineffective[29].

B. Attached Growth

To address the difficulties of harvesting microalgal biomass from suspended cultures, microalgae cells could be immobilised or attached to a support medium where the attached cells come into contact with wastewater, where the nutrients are absorbed and used by the microalgae to form biomass. The immobilised cells could be put on a revolving paddle or on a static surface[30]. The support media may be removed from the wastewater and the biomass scraped out once the appropriate degree of bioremediation had been achieved or when the biomass growth on the surface had reached a certain thickness. In addition, the leftover cells on the biofilm could serve as inoculum for the following batch.In a microbial fuel cell, a biofilm of Chlorella sp was grown as a biocathode to treat TWW and generate power[31]. Another type of connected microalgal growing system is the algal turf scrubber (ATS), which allows benthic microalgae to be grown on a solid support while wastewater is circulated through it. Similarly, an algal biofilm might be formed on the surface of a floating conveyer belt made of a dimpled metal sheet. However, one of the greatest impediments to commercialising this approach is the cost of producing the support medium[32].

4.2 Harvesting

One of the most important processes in microalgal bioremediation of wastewater is the removal of microalgal biomass from treated wastewater. If the treated wastewater is to be used for other purposes, efficient preparatory harvesting of microalgae is also required. Although there are a variety of strategies for separating biomass from the rest of the culture, the choice of harvesting technique is largely determined by the intended use of the biomass and the energy required per unit of biomass production. To create a biomass, paste with a solid content of 20% or greater, a two-phase harvesting procedure is usually used. Harvesting processes such as sedimentation, flocculation, filtering, and others are employed in the early step to create a biomass slurry (usually 1–4%), which might then be refined further (usually above 20%) using a centrifugation[33].

A. Sedimentation

Some microalgae cells were unable to stay afloat in the growth media due to their size or the medium's pH value; in either case, the cells sank to the bottom. As a result, the sedimentation technique might be used to separate microalgae biomass in large-scale operations as a low-cost, variable harvesting method. Several microalgal strains, such as Scenedesmus and Chlorella sp., have large enough cells to remain suspended in the growing medium without being mixed. The negative charge on the surface of microalgal cells inhibits cells from adhering to one another.As the density of the microalgal culture grows, the cells utilise the soluble carbonate, raising the pH of the growth fluid and potentially neutralising the microalgal surface charge. At high pH, certain inorganic substances precipitate; this process could potentially cause microalgal cells to coprecipitate. Because the slow pH increase and natural precipitation can take time, a base solution (i.e. sodium hydroxide) is sometimes used to speed up the microalgal sedimentation process[34].

B. Auto-Flocculation

Several cyanobacterial strains join together to create flocs, which are held together by the EPS they make. Several additional cyanobacteria, such as Phormidium sp., Leptolyngbya sp., and Pseudoanabaena sp., are filamentous in character and tangle together to create floc[35]. Several factors (e.g., light intensity, temperature, nutritional deprivation, etc.) may influence EPS productivity, resulting in the destabilisation of the microalgal cell surface and auto flocculation [36].

C. Bio-Floculation:

The combined biomass harvesting efficiency of a non-settling microalga and a self-settling microalga could be improved by co-cultivation. A few fungal strains (for example, Aspergillus sp.) can create gelatinous pellets in which negatively charged microalgal strains can bind and precipitate together. The fungus might exploit the available organics in wastewater as a substrate to grow and make the pellets. Similarly, bio-flocs generated by microalgae and bacteria might be extracted from treated wastewater by gravity sedimentation[37].

D. Coagulation–Flocculation

In the harvesting of microalgae from wastewater, multivalent metal salts (Fe, Al) and cationic polymers (both synthetic and natural) were found to be the most successful. For numerous microalgal strains, the effectiveness of ferric chloride and alum has been proven.Natural polymers (e.g., tan floc, chitosan, tannin, starch, gamma glutamic acid, guar gum, and tamarind kernel polysaccharide) could also boost microalgal harvesting efficiency if used at a lower dosage[38]. Recent research has shown that ferric chloride and alum collected biomass can be used to recover iron and aluminium. Furthermore, the extracted metals, in combination with a little amount of fresh coagulant, might be used to harvest biomass from the next batch of microalgal culture. Alternatively, the bacterial strain was grown separately utilising lignocellulosic materials to produce specialised bio-flocculants (e.g., xylanase and cellulase) that were shown to be very effective in harvesting microalgal strains (e.g., Chlorella minitussima)[39].

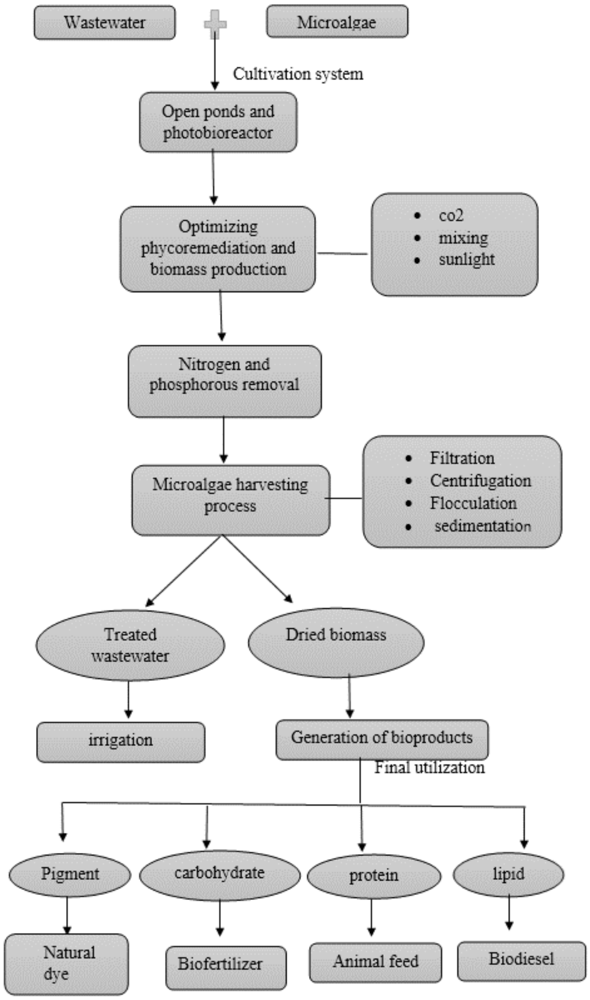
E. Filtration

Membrane filtration of microalgae culture might theoretically achieve 100% cell recovery, and unlike other methods of harvesting, membrane filtration could be used on a wide range of microalgae strains, resulting in a biomass slurry with no degradation in biomass quality. A vibrating screen setup could be utilised to separate the biomass from a filamentous strain (e.g., Arthospira sp.)[40]. Another promising biomass separation technique is tangential-flow-filtration (TFF), in which the culture is pumped through the TFF module, where a fraction of the clear water passes through the membrane while all the cells remain in the reduced volume of the culture, resulting in an increase in biomass density in the water. The TFF is used to pass the concentrated culture through until the necessary biomass density is achieved. Biomass density, cell shape, and culture salinity are some of the essential characteristics that influence membrane filtration energy consumption. Membrane fouling would occur during TFF operation; the frequency and extent of membrane fouling would be determined by the strain type, growth media composition, and TFF operation mode. Backwashing is typically performed during the TFF operation for cleaning the membrane and recovering the biomass for a short period of time. The TFF filtrate would be of good quality and may be reused for a variety of purposes[41].

G. Electrocoagulation:

The coagulants are created in situ from the anode when the electrodes (aluminium, steel, etc.) are linked to a DC power source in the electrocoagulation process. In addition to low coagulant requirements, the electrocoagulation technique has a low energy consumption (e.g., 0.3 kWh/m3). The coagulants subsequently divide the microalgal cells into big flocs, which are separated by sedimentation or floatation. Microbubbles of oxygen and hydrogen gas are created at the anode and cathode, respectively, during the electrocoagulation process. These microbubbles can cling to the coagulated algae cells and float to the surface. When comparing aluminium electrodes to steel electrodes, the efficiency of algal separation was substantially greater for aluminium electrodes[42].

4.3 Overall Mechanism



V. FACTORS INFLUENCING THE GROWTH OF MICROALGAE

5.1. Light

One of the most important limiting elements in microalgae production is light intensity. Microalgae photosynthesis is directly affected by light duration and intensity, which also has an impact on the biochemical composition of microalgae and biomass yield. Growth rate and biomass productivity are predicted as a function of light in models of outdoor or indoor algal culture systems[43]. Light intensities fluctuate within the culture and decrease as culture depth increases; this should be considered when modelling a bioreactor or open pond system. The amount of light that algae require for optimum development and biomass buildup varies by species. Microalgae cannot grow efficiently at both extremely low and very high light levels. Net growth is zero at the compensation point, where photosynthetic CO2 uptake perfectly matches respiratory CO2 release. Higher light intensities will boost photosynthetic rate to a maximum point, after which it will level off until photorespiration and photoinhibition balance the photosynthetic rate. As a result, the appropriate light intensity in each situation must be found experimentally in order to maximise CO2 assimilation while minimising photorespiration and photoinhibition. Algal photosynthesis necessitates a specified duration of light/dark intervals[44].

5.2 Temperature

Temperature is another key component in the growth of microalgae, as it has a direct impact on biochemical processes in the algal cell factories, including photosynthesis. Each species has its own ideal temperature for growth. Rises in temperature to the optimum range exponentially boost algal growth, but increases or decreases in temperature beyond the optimum point slow or stop algal growth and activity[45]. For most algae species, the ideal temperature range is 20–30 °C.Microalgae cultures grown at non-optimal temperatures lose a lot of biomass, especially in outdoor culture systems. Temperature is a crucial element in large-scale production, particularly in open-pond culture, and it requires close monitoring because algae endure significant temperature changes over time[46]. Low temperatures inhibit photosynthesis by inhibiting carbon assimilation, whereas high temperatures inhibit photosynthesis by inactivating photosynthetic proteins and disrupting the cell's energy balance.

Cell size and respiration both shrink when the temperature rises. A drop-in growth rate is caused by a decrease in photosynthesis. The main effect of temperature on photosynthesis is a decrease in the activity of the dual-function enzyme ribulose-1,5-bisphosphate (Rubisco). Depending on the proportional levels of O2 and CO2 in the chloroplasts, it can serve as an oxygenase or a carboxylase. Rubisco enzyme CO2 fixation activity increases with increasing temperature up to a point, then decreases. As a result of its effect on the affinity of ribulose for CO2, temperature is a limiting factor for algal growth rate and biomass output[47].

5.3 Nutrients

The nutritional requirements of different microalgae species may differ, but the essential requirements are the same for all. Nitrogen, phosphorus, and carbon make up the backbone of microalgae and are classed as macronutrients necessary for algal growth. Silicon is also required as a macronutrient by some marine microalgae species. Microalgae use water to absorb oxygen and hydrogen. Varied species of microalgae may have different amounts of macronutrients like nitrogen and phosphorus[48].The micronutrients Mo, K, Co, Fe, Mg, Mn, B, and Zn are only needed in minimal levels, yet they have a big impact on microalgae growth because they affect a lot of enzymatic activity in algal cells. Inorganic nitrogen and phosphorus are usually absorbed in the form of nitrates and phosphates. Other inorganic nitrogen sources, such as urea, are also a good supply and a cost-effective option. Carbon can be given to the algal culture in the form of organic compounds like glycerol or acetates, or in the form of CO2. However, in order to grow microalgae on a big scale, environmental CO2 must be used as a carbon source, which is not only inexpensive but also has the added benefit of CO2 mitigation. The key inorganic nutrients required for microalgal development are P, N, and C.

5.4 Mixing:

In microalgae production, mixing and aerating ensure homogeneous dispersion of nutrients, air, and CO2. They also allow for the penetration and even dispersion of light throughout the culture, as well as the prevention of biomass settling and aggregation. If all other parameters are met but no mixing occurs, biomass productivity will be drastically reduced. As a result, microalgae cultures must be constantly mixed to keep all cells suspended and exposed to light. In a photo-bioreactor, a correct mixing system not only allows for nutrient dissolution and light penetration into the culture, but it also allows for efficient gaseous exchange.

5.5 PH and Salinity

Another key factor impacting microalgae growth is the pH of the culture media. The pH needs of different microalgae species vary. Most thrive in a pH range of 6 to 8.76. The pH of different sources of growth medium varies. The salt of the culture media will rise as the pH rises, which is particularly detrimental to algae cells[49].

VI. CONCLUSION

Wastewater provides required nutrients in an aqueous media for microalgae production while also removing contaminants such as heavy and toxic metals, TSS, TDS, FOG, BOD, and COD. Another simulated technique using granular activated microalgae pellets proven to be a viable alternative for effective wastewater treatment. During improved cultivation in wastewater, the microalgae's natural lipid, carbohydrate, and protein contents are preserved. These natural ingredients can be used to generate energy. Microalgae's tremendous productivity, combined with a typical biofertilizer production technology, would eliminate the financial and environmental difficulties associated with chemical ones. As a result, the design of suitable high-rate algal ponds or photobioreactors for large-scale cultivation and harvesting of microalgae biomass during wastewater treatment in the context of biofertilizer generation is critical.The key problem now is to show these types of procedures on a big scale, under various conditions, and with various effluent types, as part of many industrial scale projects that are currently underway. The biomass produced is a useful resource for a variety of purposes. Biodiesel and bioethanol, as well as biogas/biomethane, can be made from microalgae biomass, with the latter being the most recommended. Furthermore, microalgae biomass can be used to provide intermediates for chemical synthesis. Microalgae biomass, on the other hand, is best used for animal feed and agriculture. Microalgae includes useful components (proteins, fatty acids, bio stimulants, and so on) that allow food production operations to increase yield while also improving sustainability and economic balance. There's no doubt that additional microalgae-based processes will be implemented in the next years, combining nutrient recovery with biomass production, increasing the relevance of microalgae biotechnology.

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