Natural Resources Conservation and Research 2024, 7(1), 4925.
https://doi.org/10.24294/nrcr.v7i1.4925

Article

Waste water treatment through microalgae and cyanobacteria

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CITATION

Rajput RS, Kumar A. Waste water treatment through microalgae and cyanobacteria. Natural Resources Conservation and Research. 2024; 7(1): 4925. https://doi.org/10.24294/nrcr.v7i1.4925

ARTICLE INFO

Received: 29 February 2024
Accepted: 18 March 2024
Available online: 17 April 2024

Abstract: Resource recovery systems for microalgae and cyanobacteria could substantially advance the recovery of nutrients from waste water by reaching the rate of effluent nitrogen (N) and phosphorus (P) below the current technology limits. However, the efficient introduction of phytoplankton involves the creation of process models that retain efficiency and simplicity in order to effectively replicate complex performance in response to environmental conditions. This research synthesises the variety of model structures that have gained from the modelling of algae and cyanobacteria and the key model features needed to allow reliable process modelling in water resource recovery facilities. Processes of cyanobacteria, including comprehensive growth prediction guidelines (under phototrophic, heterotrophic and mixotrophic conditions), nutrient absorption, carbon absorption and accumulation, and respiration are provided.

Keywords: microalgae; cyanobacteria; wastewater; biosorption; heavy metal

1. Introduction

Microalgae are microscopic and photoautotrophic cell factories given the rapid nutrients and Carbon dioxide absorption, with a high surface-to-volume ratio, with much accelerated cell proliferation. They have much higher photosynthetic efficiency and they are known to be the main atmospheric carbon synthesizers in marine environments. Micro-algae have been used in food products for human health since ancient times [1].

They feed on fish and poultry, have oils of high importance, additives, pharmaceuticals and pigments. Waste from factories that contaminate the sludge with contaminants, especially heavy metals, which are toxic if present in expanded quantities, are often found in sewage waste [2]. Without adequate treatment, an enlarged amount of sewage effluent is pumped into the marine system, deteriorating its aesthetic appeal. In addition to heavy metals, high concentrations of nutrients (especially N and P), high levels of biodegradable organic matter, fertilisers, pesticides and bad odour are recorded to contain sewage effluent. Not only does untreated waste cause eutrophication, but because of the possible involvement of multiple forms of pathogens, it is also a major health threat [3].

The danger when domestic and industrial waste is combined is so serious. In certain cases, over time, the amount of toxins is amplified, which eventually leads to a change in bacterial and algal communities into more tolerant species such as planktonic cyanobacteria, especially in the warm seasons, dominating the lake water. This species can be distinguished by their greater capacity to withstand such elevated levels of toxins and their productivity in degrading and storing heavy metals from extremely persistent organic contaminants [4]. They could also be used successfully in emerging technology for waste effluent bioremediation. The handling of waste water by microalgae cultures did not produce excess emissions when the biomass is harvested. Around the same time, it encourages proficient nutrient recycling. Several microalgae, like cyanobacteria, have been known to be used in wastewater treatment for many years [5].

Some of the microalgae strains that provide a decent alternative for biological treatment of agro-industrial waste water are *Chlorella vulgaris, Scenedesmus dimorphus, Nostoc muscorum and Anabaena variabilis, Plectonema, Oscillatoria, Phormidium and Spirulina* [6]. In the suspension community, the chosen environmental cyanobacteria species work effectively. Their use is well known for the comparatively limited period of the elimination of organic (BOD, COD, fats, oils and grease) and inorganic (Zn and Cu) as well as physical pollutants (solids, suspended and dissolved) from combined domestic-industrial waste water [7]. In addition to this, cyanobacteria are able to acclimatize quickly and produce many useful compounds in harsh conditions [8].

Few waste contaminants (including heavy metals and salts) will not be transformed into harmless products and may stay indefinitely in the ecosystem, but many other contaminants (including organic chemicals and pathogens) may be reduced at various rates to harmless components [9]. Increased eutrophication of aquatic environments can result from a rise in human population, upcoming factories and townships and the release of untreated sewage in water bodies [10]. The separation of ions by conventional techniques is incredibly costly and an endeavor that absorbs resources. The use of biological processes, however, acts as a cheap and reliable means of extracting nutrients and heavy metals from waste water. In recent years, microalgae have received greater interest, especially as an alternative bio-system for wastewater treatment throughout the tropical and subtropical areas.

Traditionally, algal systems have been used as a tertiary treatment method and they have recently been introduced as a future secondary treatment mechanism. Recovery from the processed effluent is one of the main challenges with the use of microalgae for waste water management. The technology of immobilization, which locks the cells of the microalgae into a matrix, solves the issue of harvesting to a substantial limit. A greater degree of organizational stability and fast separation are enabled by this technology. In immobilized algal biomass, several authors have recorded higher nutrient reduction efficiency than the freely suspended cells of the same genus. The choice of new biological wastewater treatment systems is primarily based on the needs of the human populations and the cost effectiveness of the systems [11].

Multiple strains of microalgae are not similarly successful in the handling of waste water. Their utility in the treatment of waste water depends primarily on two key parameters: (i) the ability of the strains of microalgae to thrive under prevailing environmental conditions and (ii) their pollutant removal performance. The activity and performance of wastewater treatment plants in areas with temperate environmental conditions (very cold/very hot and low insulation/high insulation) relies on the preference of microorganisms that are capable of proliferating under particular harsh environmental conditions. Therefore, strains of microalgae intended for remediation must pass the scrutiny of local drainage system adaptability [12].

1.1. Wastewater treatment by microalgae and cyanobacteria

Ponds used for the treatment of wastewater treatment as well as commonly used for the study of treatment processes can be classified into four major groups: maturation ponds, optional ponds, high-rate algal ponds and seedling ponds of algae [13]. A strategy for combining multiple ponds into a system called 'Advanced Integrated Wastewater Ponding System (AIWPS)' was also advocated for the treatment of microalgae wastewater. However, out of the major forms of algal ponds, high-rate algal pond is considered as one of the well-organized schemes for wastewater treatment. In addition, the function of High-Rate Algal Pond (HRAP) in secondary sewage effluent treatment has been extensively studied. HRAP systems were first considered for wastewater treatment by Oswald and later were used in other parts of the world [14].

1.2. Nutrients removal from wastewater

A huge number of nitrogenous compounds such as nitrate, urea, ammonia, amino acids, and nitrite can be digested by cyanobacteria. Atmospheric nitrogen (N_2) can also be assimilated by diazotrophic cyanobacteria. Since the reduction of dinitrogen gas by nitrogenases to ammonia is a highly exergonic process, in the form of ATP, metabolic energy is needed [15]. The ability to extract nutrients in the absence of organic carbon has commonly been used in algal pond systems for wastewater treatment. On the basis of morphological and molecular studies from the waste stabilization pond system of Sao Paulo, Brazil, the cyanobacterial genera *nostoc, limnothrix, Leptolyngbya, merismopedia* and *synechococcus* were isolated and identified. Several experiments on various scales have been undertaken to affirm the high potential of cyanobacterial organisms to extract nutrients (P and N) from polluted media and structures [16].

2. Removal of heavy metals

Heavy metals have been introduced into the atmosphere over long stretches of time by the actions of humanity. Zinc, nickel, cadmium and copper are probably the most toxic elements commonly present in significant concentrations in waste sludge. Upon release into the atmosphere, it becomes impossible to extract heavy metals by physical and/or chemical processes, and most of them have toxic effects on a broad variety of species. Sewage heavy metals bind to the organic matter that collects in the sedimentation tanks. Although the original concentration of metals might be very small, they are accumulated in the sludge by the removal of water. Precipitation, such as ion exchange, hydroxides/sulphides and oxidation/reduction, are the traditional methods used for waste effluent treatment [17]. These chemical treatments for the recycling of effluent metals before they leave the plant are not environmentally safe and costly. Therefore, the use of microbes, especially microalgae as biosorbent for metal removal, has recently created a considerable amount of interest. Microalgae are the ideal biological tool for waste water disposal because they increase the O_2 content of the water by photosynthesizing and removing some heavy metals from polluted water. Photosynthetic prokaryotes are cyanobacteria; many of them have a significant affinity for heavy metals. Additional methods for extracting heavy metals from waste water, on the other hand, have been invented [18].

2.1. Biosorption of heavy metals

Microalgae biomass biosorption of heavy metals has become an important factor in the integrated approach to aqueous effluent care. Changes in the structure of the cell wall on which the binding of metal ions takes place, as well as variations in their development under various conditions, are due to the selective absorption or degradation abilities of the chosen organisms. Multiple processes such as adsorption, ion exchange, chelation and diffusion through cell walls consist of biosorption. At the cellular level or microbial group level, these passive processes may take place. The active form of metal uptake and concentration, on the other hand, is called difficult bioaccumulation, which relies on the metabolism of cells. On prolonged interaction with the metal bearing solution, the living biomass is also able to sequester intracellular metal by an active mechanism requiring energy expenditure.

Bioaccumulation is treated as a process based on growth and is to be represented in a variety of effluents opposed to growth-independent biosorption. Consequently, in biosorption, microbial biomass can be used and exploited to a degree more effectively than bioaccumulation. The key benefits of biosorption metal recovery include the low cost and high performance of eliminating heavy metals from dissolved solutions. However, techniques would have to be built to quickly eliminate heavy metals from biomass in order not to merely relocate heavy metal contaminants [19]. The bioaccumulation of heavy metals on the surface of algae cells relies on a variety of factors, ranging from inorganic ion concentration, dissolved organic matter, pH, and particulates [20].

2.2. Step by step wastewater treatment process

The process of waste water treatment in step-by-step manner is as follows:

1) Wastewater collection: In the waste water management process, this is the first step. In order to ensure that all waste water is collected and hits a central location, recycling schemes are placed in place by city government, home owners and business owners. Via underground irrigation systems or by exhaust tracks owned or run by business owners, this water then goes to a treatment facility. However, in hygienic terms, the transmission of waste water should be carried out. The pipelines or tracks must be leak proof, or protective equipment must be worn by the persons providing the draining services [21].
2) Odor control: Odor regulation is highly necessary in the treatment plant. Wastewater comprises many polluted compounds that, over time, create a foul smell. Odor treatment procedures are initiated at the treatment facility to ensure that the surrounding environments are free from the foul smell. Using chemicals to neutralize the foul smell produced by components, all odor sources are contained and processed. In wastewater treatment facilities, this is the first and very critical step [22].
3) Screening: This is the next step in the method of wastewater treatment. Screening includes removing large items, such as nappies, cotton buds, plastics, diapers, rags, sanitary goods, nappies, face wipes, broken bottles or bottle tops that can break the equipment in one manner or another. Failure to analyze this step results in persistent issues with machinery and appliances. Specially constructed

equipment is used to collect free sand that is often washed by rainwater into the sewage pipes [23].

4) Primary treatment: The division of macrobiotic solid matter from waste water is involved in this process. For the solid matter to settle on the top of the pipes, primary treatment is carried out by deep waste water in large tanks. The solid waste slush that collects on the surface of the tanks is removed by large scrappers and forced to the middle of the cylindrical tanks for further treatment and then drained out of the tanks. For secondary treatment [15], the remaining water is then pumped.
5) Secondary treatment: The secondary treatment stage, also known as the triggered slush process, includes applying seed slush to the waste water to ensure that it does not fail to function. First, air is injected into massive aeration tanks that combine the waste water with the seed slush, which is actually a small volume of slush, which fuels the production of oxygen-using bacteria and the growth of other small microorganisms that eat the residual organic matter [24]. This method contributes to the creation of huge particles at the bottom of the massive tanks, which settle down. For a time of 3–6 h, the waste water flows into the major reservoirs.
6) Bio-solids handling: The solid matter that remains out is attached to the digesters during the main and secondary treatment processes. At room temperature, the digesters get agitated. The solid waste is then processed for a month where anaerobic digestion is performed. Methane gases are produced during this process and there is a growth of nutrient-rich bio-solids that are used in restricted companies in addition to dewatering. The methane gas emitted is commonly used in treatment plants as a source of energy [25]. This gas can also be used in boilers to generate heat for digesters for the production of electricity in engines or for the production of plant apparatus only.
7) Tertiary treatment: This process is identical to the one used for drinking water treatment plants for drinking purposes that clean raw water. Up to 99 percent of the impurities from the waste water will be eliminated from the tertiary treatment process. It creates effluent water that is similar to the consistency of potable water. Unfortunately, since it requires special equipment, well-trained and highly qualified apparatus technicians, chemicals and a constant supply of energy [26], this method appears to be a little costly.
8) Disinfection: There are also some pathogens that cause species in the residual processed waste water behind the primary treatment stage and the secondary treatment process. In order to extract them, the sewage water must be disinfected in tanks containing a combination of chlorine and sodium hypochlorite for at least 20–25 min. The method of disinfection is an important part of the process of treatment since it preserves the welfare of the animals and the local residents who use the water for other uses [27]. During local water paths, the dust (treated sewage water) is later released into the atmosphere.
9) Slush Treatment: Throughout the main and secondary treatment methods, the slush that is formed and composed involves concentrating and thickening to allow further output. It is deposited in thickening tanks to allow it to settle down and detach from the water later. It can take up to 24 h to perform this method [28].

The leftover water is gathered and sent for further treatment back to the immense aeration tanks. The sludge is then collected and sent out into the atmosphere and can be used for agricultural use. There are a variety of advantages to wastewater treatment [29].

3. Conclusions

For more than five decades, microalgae wastewater treatment has been studied as another environmental noise to eliminate nutrients and heavy metals from wastewater and thereby restore their efficiency. Due to their fast ammonium and nitrate ingestion, phosphate removal of heavy metals, modulation of physico-chemical properties of sewage waste matter and fast growth rate, several cyanobacteria organisms have been unemployed and established as a working model for such studies. Some schemes have been introduced that could contribute to more strict principles of waste matter for water treatment services located in ecologically vulnerable areas. Based on several variables, nutrient reduction efficiency, along with algal organisms, immobilization matrix, concentration of cells and beads, aeration, and preservation time, may be improved. In addition to cation concentrations, metal uptake is also influenced by light strength, pH, biofilm density, the presence of wet metal binding substances, and the resistance of individual algal species to particular heavy metals. Water hardness is a crucial factor affecting the efficacy of metal uptake because cations such as Ca^{2+} and Mg^{2+} compete with trace metals for binding sites Their potential for accelerated genetic alteration is an added advantage that could in future contribute to efficiency changes in cyanobacteria for the remediation of waste water. Microalgae have been described as effective agents to extract natural matter from impure water and, subsequently, to minimize BOD and COD. Using effective strains in fixed applications such as biofilm or immobilized cells, their ability to eliminate multi-contaminants can be seriously improved.

They may also be seen as an association with the actual role in its place, which can greatly shorten the treatment period needed for the greatest elimination. Microalgae have been found to be a more cost-effective way than activated slush to strip away the need for oxidative oxygen, bacteria, phosphorus and nitrogen. The economic potential for the treatment of microalgae wastewater can be further increased by linking the production of microalgae biomass with the treatment of wastewater and thus using resourceful methods for biomass harvesting and exposure to air metabolic and genetic engineering, approaches to systems biology, effective strain selection and high-value co-product strategy. These technologies allow microalgae to be used in polluted systems as an inexpensive and low-protection technology. The beneficial role of microalgae is still not optimally manipulated in the remediation of polluted waters in natural or manmade aquatic ecosystems. The role of bioremediation using original strains of microalgae for the sanitization of impure conjugal and industrial effluents with natural pollutants and heavy metals offers a feasible and safe solution to environmental property monitoring.

Author contributions: Conceptualization, RSR and AK; formal analysis, RSR and AK; writing—original draft preparation, RSR and AK; writing—review and editing,

RSR and AK. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

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