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ALGAE FOR WASTEWATER TREATMENT: EXPLORE THE USE OF ALGAE IN WASTEWATER TREATMENT PROCESSES INCLUDING NUTRIENT REMOVAL & BIOFILTRATION

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Abstract

Biofiltration is a mechanism by which microorganism are used to degrade and remove pollutants using a bioreactor. This concept is limited to solid liquid and gaseous pollutants. In this chapter focus is more on the removal of the waste water pollutants.The research showed that biofiltration process has been used in the treatment of municipal wastewater treatment followed by leachate, and various industrial wastewaters such as, textile, dairy, food-processing, baker's yeast, pulp, and paper. In those studies, high removal rates of carbon, nitrogen, and phosphorus parameters were reported in aerobic/anaerobic conditions using single column biological biofiltration, biological activated carbon filter, sequencing batch biofilter, or multistage biofiltration processes.Biofiltration techniques have proved to be economical and efficient in removing pathogenic microorganisms from wastewater. The current chapter focuses on series of biofiltration systems and their efficiency in pathogenic microorganism removal.This review chapter aims to present a basic understanding of the biofiltration technique and its application toward the treatment of wastewater. The chapter also discusses the application of a variety of biofilters such as anaerobic, aerobic, bacterial, algal, and mixotrophic biofilters for sewage treatment.

Keywords :Biological method, biofilteration , biodegradation, pollutants, wastewater treatment.

Highlights

- Diverse wastewater sources with variable organic contents and concentrations are treated using biofiltration.
- Biofiltration enables the development of microorganisms with relatively low specific growth rates because microorganisms are kept within the biofilm;
- Biofilters are less vulnerable to intermittent or variable loads as well as hydraulic stress;
- Biofiltration is used to remove PPCPs and lower toxicity in treated wastewater.

Introduction

One of the most crucial separating techniques for removing organic contaminants from air, water, and wastewater is the use of biofilters. Even after more than a century of use, it is still challenging to theoretically describe all the biological processes that take place in a biofilter. In this study, the mathematical modelling method is combined with a comprehensive assessment of the basic biological processes involved in the biofilter. Numerous investigations conducted over the past ten years have shown that pharmaceuticals and personal care products (PPCPs) are present in home wastewater all over the world.The biological processes frequently utilized in wastewater treatment facilities (WWTP) remove these PPCPs to varying degrees. While some PPCPs, such as ibuprofen and paracetamol, are successfully eliminated, others, such as carbamazepine and diclofenac, are only marginally impacted (Reungoat, J., Escher, B. I., Macova, & Keller, 2011). The key operational and design parameters are thoroughly covered, along with the typical values applied to various applications. The biomass that is adhered to the medium is the most significant factor that controls this process.

The relative merits of the various approaches used to measure biomass are examined. Also highlighted are the biofilter's full-scale and laboratory applications in the treatment of water and wastewater. Their accomplishments in removing particular pollutants are emphasized. (Chaudhary, D.S., S. Vigneswaran, HH Ngo, et al. 2003. For use in wastewater lift stations, the ability of biofilter systems to extract volatile organic compounds in the presence of high hydrogen sulphide concentrations was examined. The treatment system was a sealed container with a biotrickling filter and a biofilter within.(Martinez, A., Rathibandla, S., Jones, K., et al. 2008)When compared to other biological treatments, wastewater biofiltration is a unique procedure since the microorganisms are fixed to a support and the wastewater flows through it to be treated. The two main categories of biofiltration process technologies are self-attached natural systems (traditional) and synthetic fixation of microorganisms on polymeric materials (new research developments). Advanced biofiltration systems frequently offer improved biochemical oxygen demand (BOD) and suspended particles removal compared to traditional fixed film technologies because microorganisms are either immobilized on a substrate, trapped on membranes, or encapsulated.

Further, a better understanding and management of the mechanisms and parameters that promote the attachment of the biofilms to the artificial surfaces makes it possible to improve BOD and remove suspended particles from wastewater. This essay aims to examine the developments in the field of wastewater treatment using aerobic biofiltration. Each fixed film method' benefits and drawbacks are examined while highlighting various components of the treatment procedure.(2006). Verma, M., Brar, S. K., Blais, J. F., Tyagi, R. D., & Surampalli, R. Y.A green technique that is affordable and safe for the environment is biofiltration or bio-reaction (CATC, 2003; Robert and Don, 1997).

The polluted gas stream is transported through a porous medium during the biofiltration process, when microorganisms absorb and breakdown the pollutants. In order to generate energy and metabolic intermediates, microorganisms require VOCs (Van Agteren et al., 1998; Schmidt, 2012). The final products are CO_2, H_2O, and biomass. Oxides of nitrogen (NO_X) and oxides of sulphur (SO_X) are formed during the metabolism of H_2S and NH_3 (Chung et al., 2000; Malhautier et al., 2003). Biofilters primarily intended for controlling odour at municipal wastewater treatment facilities or composting operations. A potential green method for wastewater treatment called biofiltration is used to filter out several kinds of pollutants. The effectiveness of biofiltration depends on the biofilm, and the performance of the biofilm is greatly influenced by a number of variables, including temperature, dissolved oxygen concentration, organic loading rate, hydraulic retention duration, and the choice of filter media. The current biofilters make use of traditional media, including sand, gravel, anthracite, and numerous other composite materials.(Zhan et al., 2021). When opposed to using organic waste as the filter medium, the material cost of these conventional filter materials is typically higher. However, the use of organic materials as biofilter media has not been thoroughly investigated, and the literature does not adequately address their potential in terms of physicochemical qualities to encourage biofilm formation. As a result, this review critically examines the possibility of switching from conventional filter media to organic filter media in the biofiltration wastewater treatment process, focusing on factors that affect filtration efficiency, their contrasting filtration performance, benefits, and drawbacks, as well as difficulties and potential directions for organic biofilter development.

1.1 Biofiltration

One of the most crucial treatment methods utilized in the treatment of wastewater and water is filtration. Filtration is used to generate high-quality effluent that may be reused for a variety of uses in wastewater treatment, as opposed to water treatment, where it is used to make surface water fit for human consumption. A biofilter is any form of filter with connected biomass on the filter media.(Chaudhary et al., (2003).

A method of pollution control known as biofiltration uses a bioreactor filled with living organisms to collect and biologically breakdown contaminants. Processing waste water, removing dangerous substances or sediment from surface runoff, and microbiologic oxidation of air pollutants are examples of common uses. Industrial biofiltration is the process of using biological oxidation to get rid of hydrocarbons, odours, and volatile organic compounds. (Westerman et al., (1998).

The removal of trace organics from water and wastewater is a significant potential benefit of the biofiltration process. using physical separation, adsorption on the filter media, as well as biodegradation and biotransformation by bacteria creating a biofilm on the filter media, pollutants can be removed using biofiltration. This review emphasizes the value of biofiltration for secondary treatment of home and industrial wastewater as well as water treatment. The removal of assimilable organic carbon, micropollutants, and disinfection byproducts is encouraged by biofiltration water treatment. (Hozalski et al.,(1996).

After an initial ozonation phase in the process of treating water, biofiltration can be utilized as a stand-alone treatment. Incorporation of biofiltration reduces growth of biofilms in the drinking water distribution system and also prevents biofouling in downstream membrane operations. The performance of the biofiltration process is influenced by a number of variables, including filter media, empty bed contact time, filter backwash, ozonation, influent characteristics, and temperature. (Sinha et al.,(2022).In the well-established biofilm system, solid media are added to suspended growth reactors to provide attachment surfaces for biofilms. This increases the microbial concentration and rates of contaminant degradation, allowing biofilms to benefit from a variety of removal mechanisms, such as biodegradation, bioaccumulation, biosorption, and biomineralization. (Pal S.et al., (2010). Also covered is the use of biofiltration in the treatment of wastewater.Significant potential exists for the biofiltration method to remove trace organics from water and wastewater.The fundamental building block of systems for treating attachment growth wastewater is packing or filter medium. It offers the biofilm a surface on which to flourish. The filter media needs to be long-lasting, chemical-resistant, and insoluble. Its selection is based on its dimensions, porosity, density, and resistance to chemicals and erosive forces. (Christensson &Welander et al.,(2004). Using physical separation, adsorption on the filter media, as well as biodegradation and biotransformation by bacteria creating a biofilm on the filter media, pollutants can be removed using biofiltration. After an initial ozonation phase in the process of treating water, biofiltration can be utilized as a stand-alone treatment. The use of biofiltration stops the growth of biofilms in the water distribution system as well as biofouling in subsequent membrane operations. The performance of the biofiltration process is affected by a number of variables, including filter media, empty bed contact time, filter backwash, ozonation, influent characteristics, and temperature. (Sinha, & Mukherji et al.,(2022).

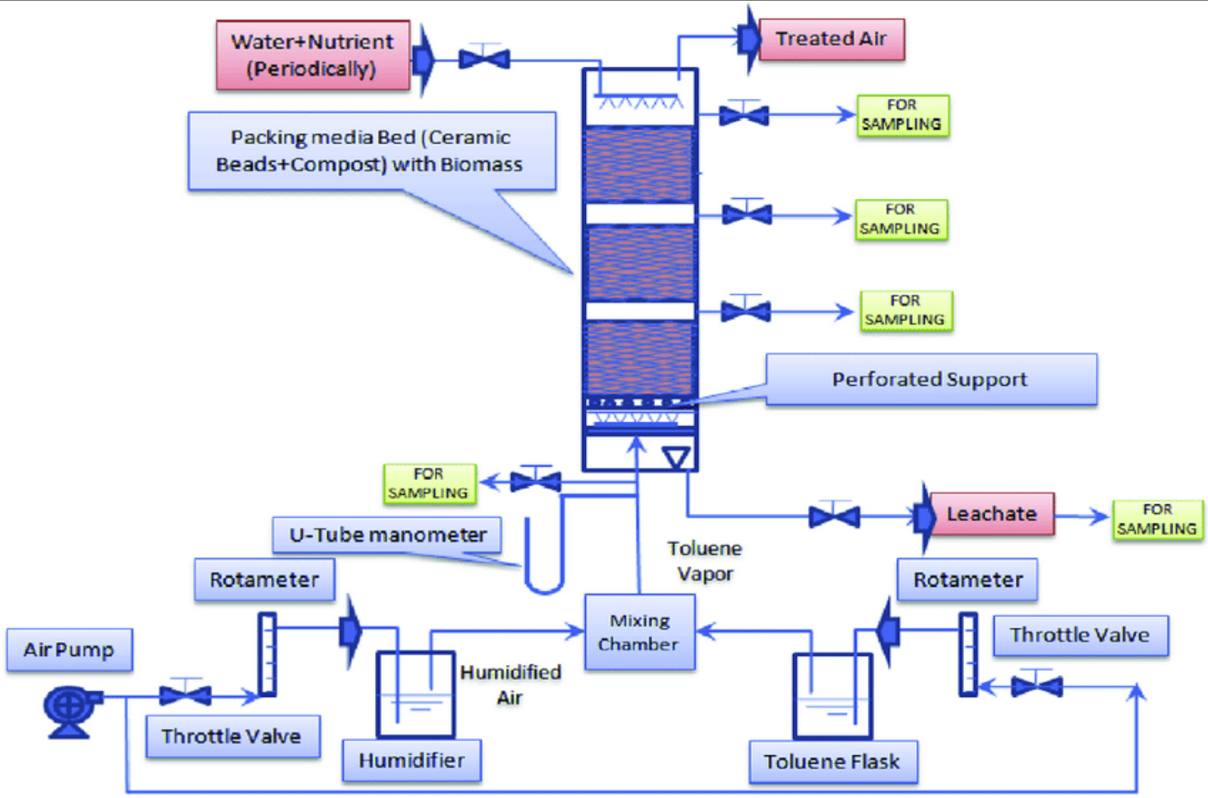

fig.1. flow diagram-experimental biofilter setup.(malakar et al., 2018)

1.2 Biofiltration process

In a biofilter, bacteria attach to and spread out to form a biofilm, a biological layer. Thus, the term "fixed-film process" is frequently used to describe biofiltration. Depending on the feeding technique (percolating or submerged biofilter), a biofilter typically contains two or three phases:

- a solid phase (media);
- a liquid phase (water); and
- a gaseous phase (air).

Where the treatment takes place, organic matter and other water components infiltrate into the biofilm, primarily through biodegradation. The majority of biofiltration procedures are aerobic, meaning that microorganisms need oxygen to function. Oxygen can be delivered to the biofilm either concurrently with or in opposition to the flow of water. Aeration can happen passively by allowing air to flow naturally through the process (using a three-phase biofilter) or by forcing air through blowers.

Water composition, biofilter hydraulic loading, media type, feeding method (percolation or submerged media), age of the biofilm, temperature, aeration, etc. are the primary determining factors. Some bacteria can colonize and attach to the surface of a biofilter's filter medium through transit, initial adhesion, firm attachment, and colonization. (Van Loosdrecht et al., 1990).

Diffusion (Brownian motion), convection, sedimentation, and active microbial mobility are the other four key processes that regulate the movement of microbes to the surface of the filter media. Microorganism attachment, substrate use, which promotes biomass growth, and biomass detachment make up the total filtration process.(Van Loosdrecht, M. C., & Heijnen, S. J. (1993).

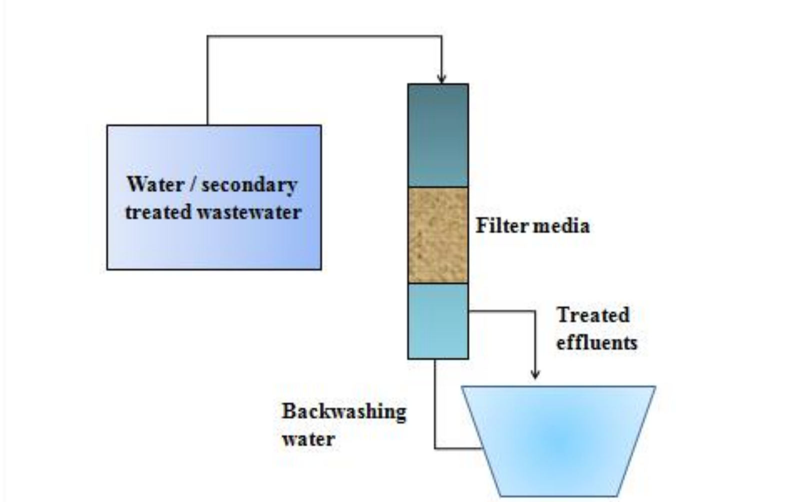

fig .2 biofiltration process for treatment of water and wastewater.(ref.sinha, p., mukherji, s. (2022)

2.1 Algal based wasteswater biofilteration

The use of macroalgae and microalgae to remove pollutants (CO2, nutrients, metals, and xenobiotics) is known as phycoremediation. It is gaining popularity because it requires little land for cultivation (solar light, CO2, and even salt water), reduces carbon emissions, and is environmentally friendly. Microalgae and macroalgae are common and grow far more quickly than most terrestrial plants, which results in higher rates of CO2 fixation. Furthermore, because the microalgal biomass is a very useful feedstock for the production of biofuels and bio-based chemicals, which proved their suitability in practical applications in bioremediation of gaseous pollutant from the source, microalgae have been considered the most effective platform for the reutilization of combustion gases (CO2, NOx, SOx). Algal-based WWT completely depends on their capacity to absorb and store nutrients in the biomass. As a result, the removal effectiveness is inversely related to biomass productivity. This elimination process restricts the use of algae to wastewater with low nutrient concentrations. The application of phototrophic algae in wastewater encounters difficulties with CO2 and light availability. For illumination, a sizable landscape is needed all together. Due to the limited organic removal capabilities of algae-based WWT, wastewater must first undergo pretreatment before entering the algal process.

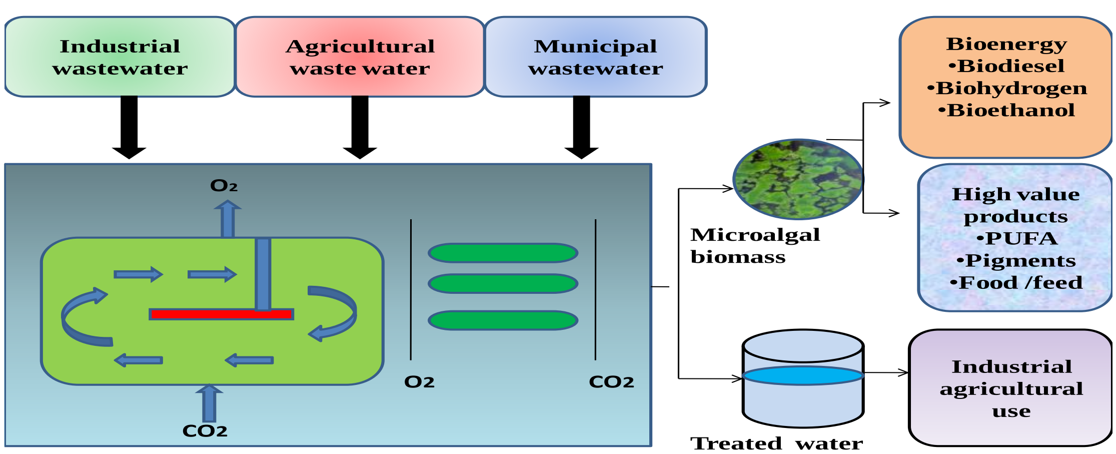

fig.2 valorization of wastewater through microalgae as a prospect for various generation for biofuel and high value products.(kumar n.,banergee c.,et al.,2022).

Table 1. provides a list of various algae species that are employed in the treatment of various wastewaters.

Algae used	Waste water	References
Chlorella spp.	Domestic Mixed, piggery and winery	Kumar et al.,(2018)
Chlorella sorokiniana	Synthetic municipal Tannery	Joon et al.,(2020)
Chlorella variabilis	Tannery	Nagi et al.,(2020)
Chlorella zofingiensis	Piggery	Zhu et al.,(2013)
Chlorella vulgaris	Sewage effluent, treatment plant, Treated piggery effluent Sewage from various drains Leather processing Textile industry	Wang et al.,(2020) & Abdel-Raouf et al.,(2012)
Chlorella pyrenoidosa	Coal gasification ,plant Dairy Alcohol sewerage + starch artificial domestic outflow	Dayana Priyadharshini et al.,(2019)
Scenedesmus sp.	Noodle processing, Primary treated, domestic drainage, Tannery	Whangchenchom et al., (2014) & Ahmad et al., (2020)
Scenedesmus dimorphus	Municipal	Xu et al., (2020)
Scenedesmus acutus	Municipal	
Scenedesmus obliquus	Treated piggery effluent Synthetic brewery effluent Food	Wang et al., (2020)
Spirulina sp.	Dairy Aquaculture	Ahmad et al., (2020) & Cardoso et al., (2021)
Spirulina maxima	Sugarcane vinasse	
Pseudochlorella pringsheimii	Tannery	
Chlamydomonas mexicana	Piggery	Abdel-Raouf et al., (2012)
Chlamydomonas reinhardtii	Sewage	
Chlamydomonas debaryana	Swine	Hasan et al., (2014)
Chlorella sorokiniana, Coelastrella sp. and *Acutodesmus nygaardii*	Piggery	Cai et al., (2019)
Neochloris oleoabundans, Chlorella vulgaris and *Scenedesmus obliquus*	Agro-zootechnical digestate	Franchino et al., (2013)
Algal-bacterial culture	Municipal	Daneshvar et al., (2019)& Delgadillo-Mirquez et al., (2016)

3.1 Factors Affecting the Efficiency of Biofiltration

A biological treatment method called biofiltration uses a number of intricate cleansing processes and operational settings. Many variables, including dissolved oxygen concentration, organic loading rate, hydraulic retention duration, temperature, and filter media, have a significant impact on how well biofiltration works. Therefore, it's crucial to note how these elements affected the creation of effective biofilters.

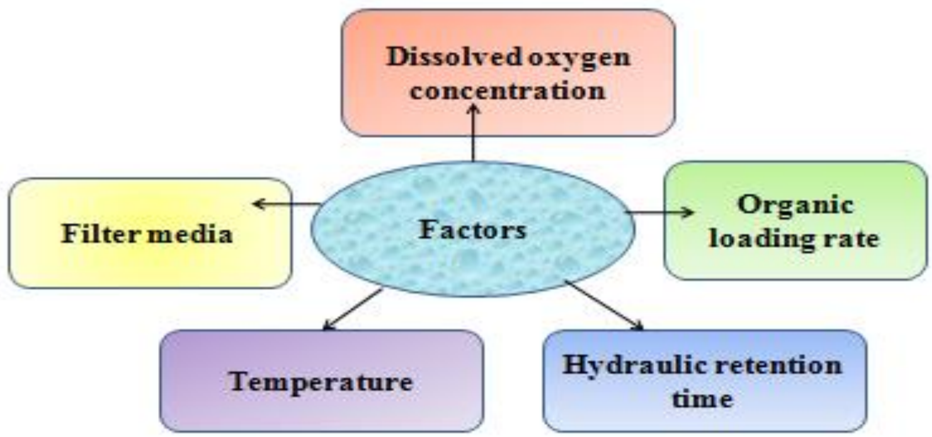

Fig.3 Various Factors Affecting the Efficiency of Biofiltration

In order to develop biological activity and encourage biodegradation in a biofilter, it's crucial to keep the concentration of dissolved oxygen high enough. The development of the microbial community in the biofilm and the effectiveness of the biological process are both significantly influenced by the amount of dissolved oxygen present. For instance, for aerobic bacteria to build a biofilm and degrade the contaminant, there must be enough dissolved oxygen from an electron acceptor. (Abu Hasan et al., 2020). In a biological aerated filter, Hasan et al. (2009) found that 2-3 mg/L of sufficient oxygen encourages the formation of nitrifying biofilms and the removal of ammonia. In contrast, a study by Kalkan et al. (2011) found that a low dissolved oxygen concentration (0.9 mg/L) promotes increased total nitrogen (TN) removal by lowering nitrification efficiency while increasing denitrification performance. This is due to the fact that heterotrophic denitrifiers carry out the denitrification process in the biofilter, where a high concentration of organic carbon sources and a low oxygen concentration favour the growth of this bacteria.(Bhattacharya et al., 2021).The development of a biofilm and water retaining capacity are both improved by increasing the organic loading rate (OLR). According to (Dalahmeh et al., 2014, p. 338) this can be explained by the stimulation of microbes to boost biological activity under the proper flux of organic matter to the biofilm. According to Lee et al. (2002), the OLR causes an increase in the production of biofilms, biomass concentration, and denitrification. However, as the OLR rises from 1.0 to 4.0 kg COD/m3 per day, the nitrification efficiency falls. Lefebvre et al. (2014) also noted that, when the OLR is low, the treated wastewater effluent almost always complies with all applicable discharge limits, whereas when the OLR is high, foaming problems arise and the removal performance becomes unstable. The microbial community structure in the biofilm is disturbed as a result of exceptionally high organic loads that prevent the substrate from moving into the interior of the biofilm due to the establishment of a dense biofilm (Dalahmeh et al., 2014 & Bhattacharya et al., 2018).Furthermore, the number of accessible adsorption sites tends to decrease as a result of high dissolved organic matter competing with the bacteria in the biofilm for adsorption sites (Lalander et al., 2013).

One of the crucial operational aspects in maintaining the biofilter's long-term efficacy is hydraulic retention time (HRT). Since the capacity of the substrate that can be handled per unit time and the effectiveness of the contact between the substrate and the microorganism are directly related to an optimal hydraulic retention time, it has an impact on the cost-effectiveness of the biofilter (Kim et al., 2013; Velvizhi et al., 2018).Since a fast-growing heterotroph prefers to grow in suspension, according to (Nogueira et al. 2002), the formation of a biofilm by slow-growing nitrifiers would take place under a relatively longer HRT. Additionally, by influencing the growth of the microorganisms in the biofilm, temperature has a significant impact on managing and regulating the performance of the biofilter. Due to slower microbial metabolism and less efficient food use, a lower temperature tends to slow down the entire biological process. The growth rate, metabolism, and community structure of nitrifiers, denitrifiers, and the concentration of dissolved oxygen are all impacted by temperature, according to Shah et al. (2002) and Zhang et al. (2019).

Because some bacteria cannot survive at low temperatures, a lower temperature reduces the effectiveness of biological treatments (Zhang et al., 2019).(Duoying, et al., 2011 & Zhang et al., 2019) reported that the temperature should be set above 18°C to create an ideal environment for nitrifying and denitrifying performance. They observed that a low temperature causes a longer acclimation period for the biofilter, such that extra contact time is needed for the less biodegradable compound to meet the specific effluent targets.

This might be explained by the various types of treated water, operational settings, and filter media employed in the studies. In order to maximize the potential of biofilters in the treatment process, more research is advised to explore and capture the effects of these elements.

4.1 Advantages of Biofiltration Over Other Filtration Methods

If you select the right biofiltration system for your industrial facility, there are six tangible benefits that you'll be provided with once the system is operating at full capacity. These advantages include:

- **Improved contaminant removal** – Biofiltration systems can more effectively get rid of inorganic, organic, and microbial contaminants when compared to conventional filtration systems.
- **Enhanced taste** – Certain compounds like methyl-Isoborneol and geosmin are usually very difficult to treat. However, these compounds can be removed with biofiltration, which reduces the possibility that the water contains musty or earthy odors and tastes.
- **Better flexibility** – This type of system also has flexibility when taking water changes into account. If the water changes over time to the point that the organism population becomes restructured, biofiltration systems should be able to remove any emerging contaminants that get into the water.
- **Lowered DBP formation** – Biofiltration systems can effectively remove organic carbon from wastewater, which lessens the possibility that such disinfection byproducts as haloacetic acids and trihalomethanes will develop.
- **Fewer solids production** – Using a biofiltration system means that the production of residual solids should be kept to a minimum. In turn, handling costs will be kept low.
- **Improved water stability** – Biofiltration is able to eliminate biodegradable dissolved organic carbon, which helps to improve water stability in your system of choice.

table.2 filtration should be looked at from a chart. biofiltration is obviously easily 80% of the game per this chart.

Water contaminants ⬇	Biofilteration	Mechanical filteration	Most chemical filteration	Ultra violets
Ammonia & nitrate	Removes	-	-	-
Bad bacteria	Removes	-	-	Removes
Pathogens like ich	Removes	-	-	Removes
Dissolved organic	Removes	-	-	-
Feces uneaten food	Removes	Removes	-	Removes
Tannic acid , dyes , smells	Removes	-	Removes	-

5.1 Challenges of Biofiltration

Despite the fact that employing a biofiltration system has many advantages, there are a few difficulties that you should be aware of. While filtered water ought to have a superior appearance and flavour, these systems have significant drawbacks when compared to more traditional filtering methods. You'll need to address decreasing filter run times as the key obstacle to overcome. While bacteria will grow more quickly in warm conditions, hydraulic restrictions may have a negative impact on the filter. The water flow might be decreased by more bacteria in the system.This particular problem can be solved by balancing the system's nutrition or by adding a straightforward disinfectant to extend run times. To complete this procedure, you can apply a disinfectant like hydrogen peroxide.

However, if you wish to employ biofiltration in warm temperatures, you might need more filters or an improved filter design. You must overcome this obstacle if you want your biofiltration system to function properly. Biofiltration systems may be the perfect solution for you if you want to utilize a filtration system that's good for the environment and can be used without using a lot of energy. Biofiltration generates water that tastes better and has less organic components than traditional sy

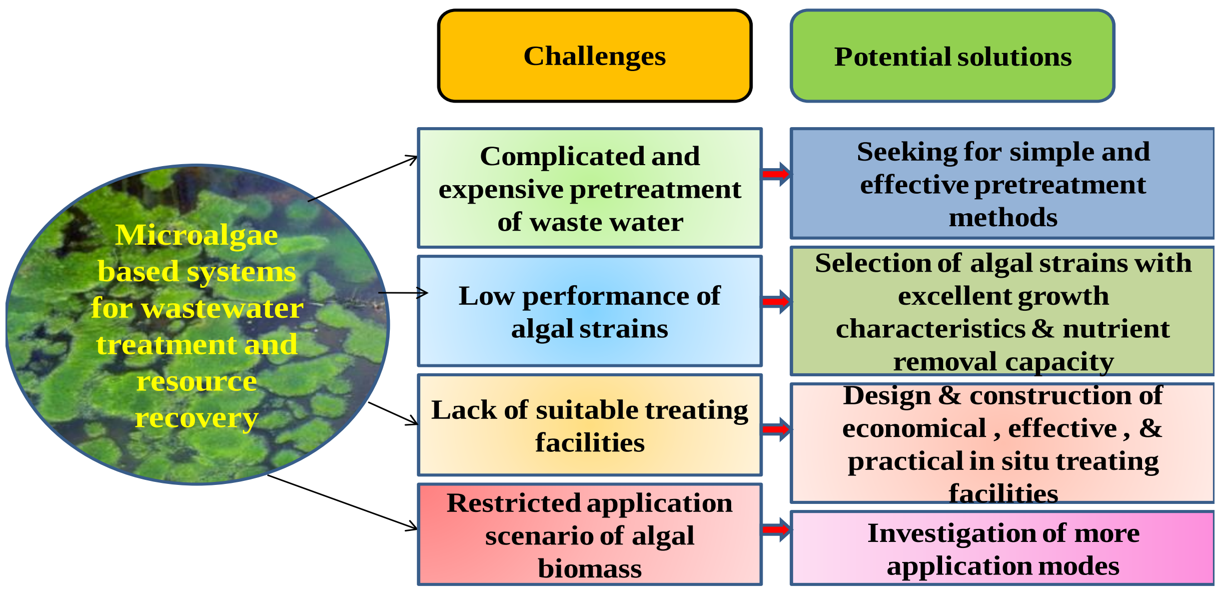

fig .4 challenges and potential solutions of microalgae-based systems for wastewater treatment and resource recovery.

CONCLUSION

Improved uses of biofiltration in drinking water treatment can be seen as green or sustainable engineering technology since they can lessen the need for chemicals in the process of treating the water. Through a better understanding of operating restrictions, recent developments in biofiltration technology for drinking water treatment have aimed to increase the performance of biofilters. In order to cleanse wastewater and create a clean environment that can be sustained, this review article illustrates the significance and necessity of biofilters. Pollutants found in wastewater are biodegraded or captured by botanical species and microorganisms. Important factors like filter bed medium, microorganisms, temperature, pH, moisture, pressure, and nutrients affect how well biofiltration works. These settings are tuned based on the contaminants to achieve high removal effectiveness. To remove various contaminants, biological-based filters are used, in which bacteria and plants act as the system's brain. By addressing the aforementioned issues, it will be possible to create biofilters that are economically feasible, technically superior, and low-investment in the future. Thanks to machine intelligence, this is achievable. Artificial intelligence (AI) has recently demonstrated its viability in a variety of fields, including water treatment (Al Aani S, Bonny T, Hasan SW, et al., 2019).It was able to forecast how different adsorbents (microbes) will behave in relation to various types and quantities of contaminants in wastewater (Briffa J, Sinagra E, Blundell R.(2020)). Due to its consistent TOC removal effectiveness, extended operational life, and ease of use, biofilter can be utilized efficiently and economically to create high quality effluent. In the near future, biologically based filters operated by AI will undoubtedly offer universally adaptable and palatable long-term solutions to the issues brought on by various pollutants.

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