A Bio Inspired Approach To Wastewater Remediation

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Abstract:

The modern world has adopted sustainable strategies to save water by increasing its reuse and recycling since overuse of water has led to the degradation and scarcity of limited water resources. Since microbial-based green technology addresses many of the drawbacks of conventional treatment systems, it has emerged as the preferred method of treating wastewater, seemingly surpassing conventional wastewater treatment (WWT) methods. This review's primary goal is to provide the many microbe kinds that are employed in diverse bioreactor setups to treat contaminated water. The advantages and uses of microbes—which clean wastewater in addition to providing a source of high-value products like biofuels and biofertilizers—are also highlighted in this overview. Moreover, it offers a critical analysis of the most recent integrated green technology techniques, such as the use of microbial consortiums for wastewater treatment. It also serves as a critical illustration of the shortcomings of green technology, which require careful consideration in order to enable its widespread expansion. The benefits of green technology are also discussed in this review, along with how they outweigh the drawbacks and advance sustainability.

Key words: Green technology, Wastewater, Microorganisms, Conventional Consortia.

Introduction:

Since water is necessary for life to exist, it is regarded as one of the most precious and important resources on Earth. Only 2.5 percent of the water on Earth is thought to be freshwater, despite estimates that water covers over 71% of the planet's surface [1]. Furthermore, the growing populace is placing enormous strain on the planet's natural resources. According to estimates, during the next 30 years, the world's populations will more than quadruple, increasing the demand for drinkable water and causing a global shortage of it. Furthermore, poor wastewater discharge and disposal from municipal, industrial, agricultural, and medical sources is a result of fast urbanization and industrialization [2]. As a result, there are now more untreated wastewater releases into the environment, endangering both human health and the environment [3]. The increasing amounts of wastewater have the following negative effects: (i) shortage of drinkable water; (ii) harm to aquatic life; (iii) contamination of land and soil; (iv) harm to groundwater; (v) increase in health risks, including death from heavy metal (lead, mercury, cadmium) contamination; and (vi) pollution of rivers and coastal areas [4]. Therefore, it is essential that both developed and developing countries take action to save water and enhance the wastewater's quality standards so that it is safe and reusable [5]. Wastewater treatment (WWT) has become a successful approach in the current situation for resolving the issues of water scarcity and safeguarding the environment against the deleterious effects of wastewater [6]. The process of safely returning pollutants and unfavorable elements back to the environment for a range of functions, including drinking, washing, irrigation, industry, and other uses, is known as wastewater treatment (WWT) [7]. The stringent implementation of government rules and growing environmental consciousness has cast doubt on conventional WWT systems in the modern era. A steady supply of oxygen (O2) is required in a traditional WWT system so that the microbes can break down and digest the complex components into simpler ones. According to calculations, the O2 demand of biodegradable carbonaceous waste in water is around 2 kg O2 kg^1 COD [8]. Maintaining such a concentration of dissolved O2 during traditional activated sludge secondary WWT thus becomes energy-intensive and quite costly. Concerns concerning the disadvantages of employing conventional WWT have also been raised by other issues, such as electricity, high sludge production, ineffective removal of emerging contaminants, and greenhouse gas (GHG) emissions [9, 10]. Because traditional WWT techniques are expensive, inefficient, frequently result in secondary pollutants, need a lot of maintenance, and need a complicated operational setup. Modern green technologies are therefore desperately needed as a sustainable replacement for traditional WWT techniques [4].

"Advanced green technology" (AGT) is a relatively recent idea among the many green Technologies used in wastewater treatment. AGT suggests lowering the hazardous substances produced by anthropogenic activities through the employment of non-toxic, energy-efficient, and environmentally friendly techniques [11]. In order to meet public requirements while preserving the remaining resources, it also envisions the economically sound recycling of natural resources. In other words, through reducing pollution, recovering energy, moderating climate change, and remediation, green technology not only ensures our well-being in the future but also protects the environment for a better one. This might be achieved by finding new approaches to create eco-friendly and clean technology to take the place of the current system [12]. In order to achieve sustainable water management, research into the use of various microorganisms, including bacteria, cyanobacteria, fungi, and protozoa, in WWT has garnered significant attention in recent years. Due to the high quantities of carbon (C), nitrogen (N), and phosphorus (P) found in wastewater from various sources, these organisms are good choices for wastewater treatment. This is because these microorganisms can use the waste in the water as their only source of C (organic and inorganic), N, and P, which is necessary for their survival and growth. Consequently, these compounds' concentration in water is significantly decreased, causing the WWT [13]. Therefore, it is expected that, if implemented properly, green technology will help to maintain efficiency, production, and prosperity while promoting green growth, strengthening sustainability, and balancing socioeconomic and environmental factors. Therefore, the goal of the current review is to offer a thorough understanding of the prospective uses of different microorganisms for WWT. Along with discussing the advantages and drawbacks of adopting green technology over traditional WWT procedures, it also sheds light on recently created cutting-edge green technologies such consortiums between microorganisms in the WWT. This review aims to provide important information to researchers worldwide who are working in relevant domains, encouraging them to consider combining microorganisms for more efficient and cost-effective WWT.

I. Role of microorganisms in wastewater treatment

In order to bioremediation wastewater and lessen its negative environmental effects, a range of microorganisms are essential to its treatment and recovery. Since these microorganisms can also break down the resistant wastes (which are typically left untreated by standard WWT processes), they hold great promise as a green technology solution for WWT. The microorganisms receive energy in return, which allows them to grow and multiply.

II. Bacteria mediated wastewater treatment

Because of their wide range of enzymatic activity and prevalence in sewage water, bacteria are the most often used microorganisms in the WWT worldwide [14]. Bacterial cells can be roughly 0.5 to 5 μm in size, and their main shapes include spherical, spiral, straight, curved, and so on. Depending on their cell shape, they can be found alone, in pairs, or in chains [15]. Bacteria can be broadly classified into two groups: heterotrophs and autotrophs. Autotrophic bacteria use inorganic materials as their C and energy source, whereas heterotrophic bacteria (such as Pseudomonas, Flavobacterium, Archromobacter, and Alcaligenes) require on organic molecules. Heterotrophs are further classified into three classes based on their requirement for O2: (i) aerobes, which breakdown organic matter in the presence of free oxygen; (ii) anaerobes, which breakdown organic matter without oxygen); and (iii) facultative, which can break down organic matter in both oxic and anoxic conditions [16].

III.Aerobic bacteria mediated wastewater treatment

These are the main microorganisms that are present in biological WWT processes, namely trickling filters and activated sludge processes. In this instance, bacteria function as biocatalysts in the aerobic biodegradation of organic substrate, which is beneficial and autocatalytic.[17]. Depending on the pH, temperature, and biological process involved, different aerobe concentrations are used; the activated sludge process uses the highest concentration of bacteria. In aerobic WWT, the activated sludge process is a widely used, low-cost technique for converting a significant amount of substrate [18]. Compared to anaerobic bacteria, aerobic bacteria have a substantially quicker metabolic rate. But the primary drawback of the aerobic mode is the overabundance of biomass formation, which is also referred to as clarifying sludge [19]. This massive amount of sludge is difficult to manage and dispose of, and it also causes major environmental problems like greenhouse gas emissions (both direct and indirect). Furthermore, the presence of high concentrations of heavy metals and other dangerous compounds makes it impossible to apply sludge as fertilizer in agriculture. As a result, sludge must be processed and treated before being finally disposed of on land [20, 21]. Furthermore, the land filling of sludge can result in the leaching of organic pollutants and toxic metals into surrounding soil and groundwater reservoirs, which can ultimately cause secondary pollution [22]. As of right now, a number of AGT techniques have been tried, tested, and used in conjunction with or apart from conventional WWT techniques, including:

i. Fixed-bed bioreactors.

The chambers of this bioreactor, which is constructed of many chambered tanks, are densely packed with porous ceramic, foam, and plastic media. Wastewater can flow over the immobilized media bed in this configuration because it is made with a surface area that is adequate to promote the development of robust and long-lasting biofilm. As a result, sludge generation and disposal expenses are reduced [23].

ii. Moving bed bioreactors.

Typically, it consists of aeration tanks with tiny, mobile biofilm carriers (made of polyethylene) attached to the inside of the vessel by media retention sieves. These bioreactors are trailed by a secondary clarifier, which forces excess sludge to settle down, filter pressed, and disposed of as solid waste. They are ideal for treating high Biochemical Oxygen Demand (BOD) wastewater in a small area without the need for plugging [24].

iii. Membrane bioreactors.

In order to separate the suspended solids, this improved version of the biological WWT method uses membrane filtration rather than sedimentation or settling down. In comparison to the traditional activated sludge method, it offers significantly better results and operates well with longer solid residence durations and greater mixed liquid suspended solids (MLSS) due to this filtration principle [25].

IV. Microalgae mediated wastewater treatment

Microalgae, which are photosynthetic microorganisms that include cyanobacteria and eukaryotic algae, are promising agents for the biological treatment of wastewater, known as bioremediation [26]. They are an environmentally responsible and sustainable method of eliminating heavy metals, fertilizers, and other organic contaminants from industrial and

municipal wastewater [26]. The approach that often employs algae species for bioremediation has been dubbed "phycoremediation" [27]. The algae Tetraselmis sp., Chlorella vulgaris, Chlorella sp., Picochlorum sp., Scenedesmus sp., etc. are the most

commonly employed taxa for phytoremediation.[5]. For phycoremediation, many cyanobacterial strains are also employed, including Anabaena sp., Dolichospermum sp., Hapalosiphon sp., Scytonema sp., Leptolyngbya sp., Chroococcus sp., Pseudospongiococcus sp., Gloeocapsa sp., Lyngbya sp., Oscillatoria sp., Synechocystis sp., and Spirulina sp. [14].

V. Recent biotechnological green technology for wastewater remediation

Numerous green biotechnological techniques have been published recently for the treatment

of various wastewater types [2]. The formation of a consortium involving plant systems and microorganisms can offer a more sustainable approach to wastewater cleanup [5,6,15]. They break down the polymeric pollution into monomer forms and use it as a source of nutrients [2]. In the remediation process, positive interactions between species of the same or other genera are seen as emergent green technology [11]. The formation of plant consortia or plant bacteria-based floating treatment wetland macrocosms in bacteria aids in the concurrent degradation of pollutants, and the plant uses the pollutant as a source of nutrients for growth [19].

VI. Limitations of green technology

Even though green technology has advanced significantly over the years and is now recognized as a sustainable strategy in WWT, there are still a number of issues that need to be addressed. In addition to being economical and environmentally benign, biological treatment is limited in its wide-ranging applications by parameters like pH, temperature, and seasonal variations. Regretfully, there is no mention of these limits in any literature. However, there are a number of problems that must be overcome if this technology is put into practice. For instance, maintaining the ideal flow rate, controlling the thickness of the biofilm, longer start-up times, pumping facilities, odor-related problems, packing material costs, and inefficient performance (if the suspended solid concentration is high) are challenges faced by bioreactors based on bacterial biofilm [14]. Large areas are also necessary for optimal and consistent exposure to sunlight in the case of WWT using a microalgal pond system [14]. Moreover, the design of photobioreactors has some drawbacks, such as an excess of dissolved oxygen that inhibits photosynthetic activity and a build-up of biofilms on the inside surfaces of the reactors that hinder light penetration.

Seasonal variations in lighting intensity also affect photobioreactors installed outdoors [25]. Fungal bioreactors also present a number of challenges, including: (i) mass transfer limitations; (ii) fluid flow pattern by-passing; (iii) maintaining sterile conditions because fungal bioreactors are susceptible to bacterial contaminations; (iv) removal of surplus biomass; (v) formation of dead zones; (vi) requirement for high maintenance throughout the operation; (vii) unfeasibility at large volumes; (viii) inadequate mixing at high densities; (ix) excessive agitation can shearing of pellets, which may interfere with enzyme production; and (x) foaming due to vigorous aeration resulting in loss of uses.

VII. References

1. A. Shahat, M.R. Awual, M.A. Khaleque, M.Z. Alam, M. Naushad, A.M.S. Chowdhury, Large-pore diameter nano-adsorbent and its application for rapid lead (II) detection and removal from aqueous media, Chem. Eng. J. 273 (2015) 286–295.
2. R.K. Goswami, S. Mehariya, P. Verma, R. Lavecchia, A. Zuorro, Microalgae-based biorefineries for sustainable resource recovery from wastewater, J. Water Proc. Eng. 40 (2020) 101747.
3. X. Qu, Y. Zhao, R. Yu, Y. Li, C. Falzone, G. Smith, K. Ikehata, Health effects associated with wastewater treatment, reuse, and disposal, Water Environ. Res. 88 (2016) 1823–1855.
4. T. Vasantha, N.V. V Jyothi, Green technologies for wastewater treatment, in: Green Methods Wastewater Treat, Springer, Cham, 2020, pp. 217–253.
5. R.K. Kumar, K. Agrawal, S. Mehariya, P. Verma, Current perspective on wastewater treatment using photobioreactor for Tetraselmis sp .: an emerging and Foreseeable sustainable approach, Environ. Sci. Pollut. Res. 67 (2021) 1–33.
6. R.K. Goswami, K. Agrawal, P. Verma, Phycoremediation of nitrogen and phosphate from wastewater using Picochlorum sp.: a tenable approach, J. Basic Microbiol. (2021) 1-17.
7. B.S. Choudri, Y. Charabi, Health effects associated with wastewater treatment, reuse, and disposal, Water Environ. Res. 91 (2019) 976–983.
8. C.P.L. Grady Jr., G.T. Daigger, N.G. Love, C.D.M. Filipe, Biological Wastewater Treatment, CRC press, Boca Raton, 2011, pp. 1–963.
9. S. Longo, B.M. d'Antoni, M. Bongards, A. Chaparro, A. Cronrath, F. Fatone, J.M. Lema, M. Mauricio-Iglesias, A. Soares, A. Hospido, Monitoring and diagnosis of energy consumption in wastewater treatment plants. a state of the art and proposals for improvement, Appl. Energy 179 (2016) 1251–1268.

10. J. Wan, J. Gu, Q. Zhao, Y. Liu, COD capture: a feasible option towards energy self-sufficient domestic wastewater treatment, Sci. Rep. 6 (2016) 1–9.
11. C.H. Neoh, Z.Z. Noor, N.S.A. Mutamim, C.K. Lim, Green technology in wastewater treatment technologies: integration of membrane bioreactor with various wastewater treatment systems, Chem. Eng. J. 283 (2016) 582–594.
12. H.H. Ngo, W. Guo, R.Y. Surampalli, T.C. Zhang, Green technologies for sustainable water management, in: American Society of Civil Engineers, 2016.
13. S.F. Mohsenpour, S. Hennige, N. Willoughby, A. Adeloye, T. Gutierrez, Integrating micro-algae into wastewater treatment: a review, Sci. Total Environ. 752 (2021) 142168.
14. A.L. Nascimento, A.J. Souza, P.A.M. Andrade, F.D. Andreote, A.R. Coscione, F.C. Oliveira, J.B. Regitano, Sewage sludge microbial structures and relations to their sources, treatments, and chemical attributes, Front. Microbiol. 9 (2018)
15. K.D. Young, Bacterial morphology: why have different shapes? Curr. Opin. Microbiol. 10 (2007) 596–600.
16. K.J. Hellingwerf, W. Crielaard, W.D. Hoff, H.C.P. Matthijs, L.R. Mur, B.J. Van Rotterdam, Photobiology of bacteria, Antonie Leeuwenhoek 65 (1994) 331–347.
17. V. V Ranade, V.M. Bhandari, Industrial wastewater treatment, recycling, and reuse: an overview, in: Industrial Wastewater Treatment, Recycling and Reuse, Elsevier Ltd., Oxford, 2014, pp. 521–535.
18. U.S.E.P.A. (USEPA), Wastewater Treatment Manuals: Primary, Secondary and Tertiary Treatment, 1997.
19. Milieu Ltd, Environmental, economic and social impacts of the use of sewage sludge on land Final Report Part II: report on Options and Impacts. https://ec.eur opa.eu/environment/archives/waste/sludge/pdf/part_ii_report.pdf, 2008.
20. R.P. Singh, M. Agrawal, Potential benefits and risks of land application of sewage sludge, Waste Manag. 28 (2008) 347–358.
21. M. Reilly, The case against land application of sewage sludge pathogens, Can. J. Infect Dis. 12 (2001) 205–207.
22. A. Pathak, M.G. Dastidar, T.R. Sreekrishnan, Bioleaching of heavy metals from sewage sludge: a review, J. Environ. Manag. 90 (2009) 2343–2353.
23. W. Guo, H.-H. Ngo, F. Dharmawan, C.G. Palmer, Roles of polyurethane foam in aerobic moving and fixed bed bioreactors, Bioresour. Technol. 101 (2010) 1435–1439.
24. L.W. Jaroszynski, N. Cicek, R. Sparling, J.A. Oleszkiewicz, Impact of free ammonia on anammox rates (anoxic ammonium oxidation) in a moving bed biofilm reactor, Chemosphere 88 (2012) 188–195.
25. X. Zhao, Z. Chen, X. Wang, J. Shen, H. Xu, PPCPs removal by aerobic granular sludge membrane bioreactor, Appl. Microbiol. Biotechnol. 98 (2014) 9843–9848.
26. B. Zhang, Q. Yu, G. Yan, H. Zhu, X. yang Xu, L. Zhu, Seasonal bacterial community succession in four typical wastewater treatment plants: correlations between core microbes and process performance, Sci. Rep. 8 (2018) 1–11.
27. D. Pant, A. Adholeya, Biological approaches for treatment of distillery wastewater: a review, Bioresour. Technol. 98 (2007) 2321–2334.