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Algae and Seaweeds as Environmental Friendly Water Bio-Remediation Source

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ABSTRACT

Algae are becoming one of the most promising and sustainable sources for cultivated biomass that produces considerable yields and oils that can be used for the production of biofuel, food, feed, and other useful products. In some countries, algae are used for fuels production to help reducing the national dependence on fossil fuel and for water remediation to save the environment. There are various conventional methods; including physical, chemical and biological methods are used for water treatment and to remove insoluble particles and soluble contaminants from waste effluents. The major disadvantages of these methods are the high initial cost for energy, maintenance and operation cost. In addition, most of these methods need specific experiences. In recent time, other conventional and non-conventional wastewater treatment technologies are using wastewaters treatment, of which, membrane filtration technologies and advanced oxidation processes (AOPs) were the most significant. In the twentieth century, advanced technologies, such as bio-remediation and nanoparticles are documented pollutants removal. Several studies were conducted to evaluate the use of biological treatments and to determine any lack and/or insufficiency in their application. Algae, among other biological agents, showed great potentiality for the removal of toxic chemicals from wastewater and for metal reduction. On finding the specific characterization and capabilities of nnanotechnologies (NTs), it has been used to purify the environment by detection, prevention and removal of toxic pollutants and environmentally friendly products. Various types of algae are now used in NT and have shown positive potentiality for green synthesis with several advantages which include easy harvesting, handling, and disruption of cells, high accumulation potential, faster doubling rate, low risk, cost, and toxicity, increased energy efficiency, and easy scalability.

Background

Algae are becoming one of the most promising, sustainable sources of cultivated biomass that produces considerable yields and oils that can be used for the production of biofuel, food, feed, and other useful products. Therefore, a recognised wave of great interest in algal cultivation has increasingly considered worldwide; this is mainly due to their potential abilities to produce important and useful products; including such as biofuels (e.g. algal-based biofuel; ABB) of several types of biofuels; like methane (Chisti [1]); biodiesel (Roessler, et al. [2,3]; and bio-hydrogen (Fedorov, et al. [3]; Kapdan & Kargi, 2006) as well as other algal-based

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products for water pollution treatment. Almost all algal species, either microscopic or large kelps are aquatic photosynthetic organisms that are capable to grow successfully in varied climate status producing huge annual yield. Algae are economically and ecologically important group of photosynthetic organisms. They are unicellular or multicellular organisms dwelling in different environment such as freshwater, marine water, or surface of moist rocks (Oscar, et al. [4]).

Algae are categorized as microalgae (microscopic) and macroalgae (macroscopic). They play a key role in medical, pharmaceutical, agriculture, aquaculture, cosmetics applications. Algae are a valuable source for various commercial products such as natural dyes and biofuels (Borowitzka [5]). Algal cultivations are valuable for several bio products and the algal-based fuels, for example, help reducing the national dependence on fossil fuel in some countries and minimizing the global warming and climate changes. The use of algae for water remediation is another great benefit that algae can provide and saving the environment through chemical and physical treatments and protect the aquatic environments from excessive pollution. There are several reasons that makes algae and seaweeds are much favoured, such as the easy methods for cultivation, the high productivity large biomass produced and the year-round production as well as the various environmental and socio-economic benefits associated with their cultivation process.

Why Algae and Seaweeds?

What really makes algae much exciting and worth expanding their culturing is the fact that they have been naturally exist since billions of years growing, reproducing and storing energy within their cells as bio-products such as starch, oil or other compounds. They include various species/strains with various forms and structure and are potential able to convert CO_2 to produce different bio-products; such as fuel, food, feed, cosmetics, other bio-active materials (Metting, et al. 1986. Vimali, et al. 2021) and many other industries. Moreover, those micro-algae are efficient as bioremediation agents (Mallick 2002; Kalin, et al. 2005; Muñoz, et al [6]; Sierra, et al. 2021) and as nitrogen-fixing fertilizers (Vaishampayan, et al. 2002; Chittapun, et al. 2018). Therefore, it becomes more crucial to encourage the research to study "algae" and strengthen our understanding to be much aware of all its numerous and unlimited benefits. Algal populations are greatly diversified with respect to size including microscopic species that are so-called microalgae and to giant species or the seaweeds (macro-algae) having species with more than one hundred feet length. Algal Cultivation can be achieved under different culturing conditions; i.e., photoautotrophic, mixotrophic, or heterotrophic. If they grow photo-autotrophically, they utilizes light to reproduces and provide new cells/biomass, however in heterotrophic cultivation method algae only require a carbon source for energy (e.g. sugars), instead of light (Kamalanathan 2018). In mixotrophic cultivation, algae are able to use both or any of the energy sources (light or a carbon) to grow and provide biomass yield. Heterotrophic and mixotrophic cultivation strategies are more preferred since high biomass yield could be achieved when relying on any carbon source, which is also cost effective (Xu, et al. 2006).

Water Pollution Remediation

Early in the 20th century, several water treatment methods were established and many of which are still using till current; those methods include mechanical separation, coagulation, chemical purification, disinfection, biological treatments, aeration, and boiling (Hazen 1914). In addition, various conventional methods are used for water treatment to remove insoluble particles and soluble contaminants from effluents (Crini, et al. 2019); including physical, chemical and biological methods. The major disadvantages of these methods are the high initial cost, energy cost, maintenance and operation cost as well as the need specific engineering experts for equipment handling and other difficulties related to transport and storage issues (Xiaodong Xin, et al. 2012; Berefield, et al. [7]). Recently many conventional and non-conventional wastewater treatment technologies are available to remove pollutants from various types of wastewaters, of which, membrane filtration technologies and advanced oxidation processes (AOPs) were the most significant editions to the water treatment world. In the twentieth century, Recent technologies, such as bioremediation and NPs, can provide valuable approaches for the removal of pollutants from the environment and are currently the worldwide basis of wastewater treatment. Several studies were conducted to evaluate the use of biological treatments (e.g., activated sludge and biological trickling filters) and to determine any lack and/or insufficiency in application (Servos, et al. [8-10]).

Algal Bioremediation

Bioremediation has emerged as an eco-friendly remediation and low-cost alternative to conventional remediation technologies. This approach is mainly depending on ability of microbes; including algae, fungi, and bacteria to degrade organic and inorganic pollutants from industrial wastewaters (Bharagava, et al. [11]). Wastes are converted into inorganic compounds (e.g., CO_2) through bioremediation process detoxify the polluted water (Reshma, et al. [12]). Bioremediation technique normally involves bio-attenuation, bio-stimulation, and bio-augmentation (Maszenan, et al. [13]). However, bioremediation may be facing some restriction; such as pollutants low or non-bioavailability to microbes, toxicity of pollutants to microbes and any remediating plants, the lack of enzymes that responsible for pollutants degradation and detoxification, and in some cases the low biomass and/or slow growth rate of the used remediating plants. This in addition to the strict regulations conducted in USA and some western countries to regulate the use of these organisms and restrict their field applications. Using algae in bioremediation has gained importance due to their potential to absorb or accumulate toxic metals from the contaminated environment (Mitra, et al. [14]). Algae were investigated for the removal of toxic chemicals from wastewater (Zeraatkar, et al. [15]) and more than 80% of the total reports conducted from 2011 to 2015 showed the potential effect of algae for metal reduction. Metal-removal capacity was reported in a water system using microalgae (Gosavi, et al. [16]) with some specific species (Pseudochlorococcum typicum, Scenedesmus quadricauda, and Phormidium ambiguum) tested successfully as removing agent for mercury, lead, and cadmium (Shanab, et al. [17]). Similarly, Moreover, large -sized algal biomass was also applied for the removal of waste from water (Romera, et al. [6]), of which, Phaeophyta are the most studied and effective phylum, with the best results for bio-recovery.

Algal Nano-Bio-Remediation

Nano-bio-remediation is the currently new concept in water treatment field. It integrates the bioremediation approach with the use of nanoparticles in one technique for sustainable remediation of environmental pollutants in the contaminated matrix (Cecchin, et al. [18]). This approach has recently received much attention for the remediation of contaminated sites (Lin, et al. [19,20]). Nanotechnologies (NTs) are considered the novel solution for several problems, including, water scarcity and water pollution/ water treatment. It offers a potential role to purify the environment by detection, prevention and removal of toxic pollutants and thus is being integrated into cleaner industrial processes and producing environmentally friendly products. Among the biological materials, algae are called as 'bio-nano-factories' because both the live and dead dried biomasses were used for the synthesis of metallic nanoparticles (Davis, et al. [21]). Algae are economically and ecologically important group of photosynthetic organisms. They are unicellular or multicellular organisms dwelling in different environment such as freshwater, marine water, or surface of moist rocks (Oscar, et al. [4]). Algae are categorized as microalgae (microscopic) and macroalgae (macroscopic). They play a key role in medical, pharmaceutical, agriculture, aquaculture, cosmetics applications. Algae are a valuable source for various commercial products such as natural dyes and biofuels (Borowitzka [5]). Various types of algae have Positive attributes explored them as a potential tool for green synthesis which include easy harvesting, handling, and disruption of cells, high accumulation potential, faster doubling rate, low risk, cost, and toxicity, increased energy efficiency, and easy scalability (Sharma, et al. [22]). Among different biological processes, algae show more positive outcomes because of their large-scale bioproduction of metal NPs.

All these properties make algae model organisms for the synthesis of bionanomaterials. Consequently, the study of algae-mediated biosynthesis of nanometals can be considered as a newer branch, phyconanotechnology. Till now, for the biosynthesis of metallic NPs, different groups of algae such as Chlorophyceae, Phaeophyceae, Cyanophyceae, Rhodophyceae, and others (diatoms and euglenoids) have been used (Sharma, et al. [22]). Numerous species of brown algae (such as Cystophora moniliformis, Sargassum polycystum, Padina pavonica,and Gelidiella acerosa) were reported for the production of silver nanoparticles AgNPs; (Azizi, et al. [23]), and some other species (such as Cystoseira baccata, Fucus vesiculosus, Ecklonia cava, Dictyota bartayresianna, and Sargassum wightii) showed their contribution in the biosynthesis of AuNPs. The biosynthesis of AgNPs by a variety of red alga strains such as Kappaphycus alvarezii, Gelidiella acerosa, and Kappaphycus sp., and gold nanoparticles by other species such as Chondrus crispus, K. alvarezii,and Galaxaura elongata was studied (Castro-Longoria, et al. [24]). In addition, the synthesis of AgNPs with different morphologies can be obtained by using various BGA species such as Oscillato riawillei, Spirulina platensis, Microchaete diplosiphon, Plectonema boryanum,and Cylindrospermum stagnale (Bhattm et al, 2021; Hussain, et al. [25]). S. platensis and Phormidium valderianum are well-known for the biosynthesis of AuNPs e.g., (Shukla, et al. [26]). Several strains of cyanobacteria (Singh, et al. [27,28]), and microalgae (Khatoon, et al. [29]) showed the reductive conversion of a wide range of metals to nanometals (Mahdavi, et al. [30-32]).

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