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Research Article

Use of microalgae as a biosensor for bioremediation of emerging contaminants

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Abstract

Emerging contaminants are a worldwide concern as a result of continuous discharge from various domestic, agricultural, and industrial activities that lead to potential health concerns. Microalgae is used as a biosensor to identify contaminants in wastewater and by the process of bioremediation to get rid of those contaminants so that the water is purified and everyone has the excess to clean drinking water. In addition to cleaning wastewater and addressing pollution issues, microalgae-based wastewater treatment technology may use nutrients in wastewater to produce algal biomass, which is becoming more and more popular. Microalgae can reduce levels of nitrogen and phosphate as well as other hazardous substances like heavy metals or pharmaceuticals, making them potential candidates for wastewater recovery. Due to their use of sunlight as their primary energy source, photosynthetic microalgae require less energy input than conventional systems, which reduces the process' overall carbon footprint.

Keywords: Biosensors; Bioremediation; Emerging Contaminants; Microalgae; Wastewater Treatment

Introduction

Emerging contaminants are a global concern as a result of continuous discharge from various domestic, agricultural, and industrial activities, which can cause health problems. ECs pose serious ecological threats and may endanger human health and aquatic life **[1]**.

Municipal, agricultural, and industrial wastewater contains a variety of organic and inorganic contaminants, such as microplastics, xenobiotics, heavy metals, high quantities of nitrates, phosphates, and carbon (C) compounds **[2]**. Especially when there are many contaminants present in the wastewater, the majority of conventional wastewater treatment facilities now in use are not constructed effectively to remove or bioremediate ECs.

It has been demonstrated that microalgal-based wastewater treatment systems are more effective at resolving nutrient contamination than conventional wastewater systems, have cheaper capital and operating costs, and provide natural disinfection **[3]**. Because they may build up biomass, reduce N, P, and C in the wastewater, and increase nutrient recovery while utilizing both organic and inorganic carbon, nitrogen, and phosphorous **[4]**. Several microalgal species, including *Scenedesmus*, *Chlorella*, *Botryococcus*, *Phormidium, Limnospira* (previously Arthrospira, Spirulina), *and Chlamydomonas*, are excellent at nutrient bioremediation **[5]**.

The ability of phototrophic microorganisms to provide oxygen to aerobic organic pollutant degraders and enhance the removal of nutrients and pathogens is essential for the use of microalgae in wastewater treatment **[6]**. Several microalgae can even remove heavy metals from industrial wastewater through biosorption **[7]**.

Utilizing biological materials' capacity to remove heavy metals from wastewater, the biosorption approach via physicochemical or metabolically driven absorption mechanisms. To find more effective and affordable metal-removal biosorbents, The use of biosorbents/biomass from various microbiological sources, including moss, aquatic plants, and leaf-based adsorbents, has been documented by several studies. Microalgae are shown to have high metal binding capacities due to the presence of polysaccharides, proteins, or lipids on the surface of their cell walls that can act as binding sites for metals **[8]**. Due to their low nutritional requirements, high absorption capacity, high ratio of surface to volume, and low production volume that successfully degrades toxins and cleans the environment, algae have attracted a lot of interest as a biosorbent **[9]**.

The phenomenon known as "laser-induced fluorescence" (LIF) which occurs when laser light causes pigments inside a cell to fluoresce—is one of the most important aspects of single-celled algae. A LIF spectrum depends on the makeup of the pigments in the microalgae cells as well as the external environmental factors that influence the metabolic reactions that take place there.

Microalgae-based biosensors are effective biosensors that work by using cell suspensions of green microalgae. Toxicants cause changes in the luminous properties of chlorophyll-a, which is a component of these algae's PS2 photosynthetic system. Using a fluorometer, the fluorescence of microalgae is measured in the 680–690 nm wavelength region. By comparing the change in fluorescence intensity to its starting value, it can identify the existence and concentration of toxicants in water (before toxic effects) **[10]**.

As a result, both the environmental effect and overall treatment costs are decreased. Consequently, employing microalgae can contribute to lowering global warming without producing pollution.

Materials and Methods

Collection of Algal Samples

We collected 100 Algal samples from various locations, and then we examined them under the microscope for additional confirmation.

Bioremediation of emerging contaminants (Using biosorption technique)

A type of bioremediation method called biosorption can be developed to remove and degrade pollutants in water without releasing any hazardous byproducts **[11]**. For this step, we selected marine water as our sample. A few contaminants, such as metal ions and dirt particles, were additionally added from an external source for further confirmation of the impurities. Algal biomass (e.g. *Chlorella vulgaris*) was then added to the sample as an inoculant, then we centrifuged it for 5 minutes to help the contaminants adhere to the cell surface.

Measurement of contaminants

To measure the pollutants, we employed a fluorimeter with a 680–690 nm wavelength range. We examined wastewater samples containing algae at three different intervals: 0 minutes, 45 minutes, and 24 hours. When compared to its initial value (before toxic effects), we observed a shift in fluorescence intensity, which allowed us to calculate the toxicity and concentration of pollutants.

Nano filtration

We employed a nanofiltration technique for further purification. Nano-filtration filters can get rid of bacteria and viruses because they have pores as small as 0.001 microns. It performs the dual roles of a semi-permeable membrane that can filter out ions and a barrier membrane that can exclude particles as small as 0.005 to 0.001 microns **[12]**. We applied this procedure to further clean the water and get rid of the algal cells.

Results

We have identified 25 species of *Chlorella vulgaris* using the microscopy of isolated samples as shown in (Fig. 1), and the results of processing these 25 samples are as follows.

Bioremediation

After the bioremediation process, we observed that the water pollutants bonded with the algae and collected as sediment in the tube, yielding clear water as the supernatant (Fig. 2).

Measurement of contaminants

The Fluorescence of a wastewater sample containing an algal sample at time intervals of 0 minutes, 40 minutes, and 24 hours allows us to evaluate the following readings. We saw a decline in fluorescence as time went on as mentioned in (Table 1). This demonstrates that the developing contaminants in wastewater adhere to the cell walls of algae and generate blockages, which reduce the ability of microalgae to produce fluorescence.

Result of nanopore filtration

After performing Nanopore filtration using a nanopore filter assembly, we obtained completely pure water as shown in (Fig. 3).

PH Test

The treated water sample's pH is 7, indicating that it is fit for human consumption (Fig. 4).

Discussion

In this study, we showed that microalgae might serve as biosensors for the detection of contaminants, including heavy metals, herbicides, and volatile organic compounds. These micro-algal biosensors have the main benefit of allowing frequent measurements to be taken without requiring intensive sample preparation **[13]**. It also demonstrated the role of algal biomass in the removal of metals, organic pollutants, and carbon dioxide **[14]**. A potential source for wastewater bioremediation is algae biomass due to its low cost of production and suitability for environmental factors (For example, pH, contact time, and temperature) **[15]**. The removal of pollutants throughout the treatment process results in the creation of clean, drinkable water. Nitrogen and phosphorus may be effectively removed from wastewater by microalgae. It is environmentally beneficial by reducing infections, pollutants, and atmospheric CO_2. It can recover resources through the biorefinery of microalgal biomass, which can be used to create both high-value and low-value goods. In addition to slowing eutrophication rates and increasing dissolved oxygen levels in the water, microalgae growth and application is a possible technique for the recovery of resource-constrained populations and difficult-to-reach water bodies (pigments, enzymes, sugars, and lipids) **[16]**. Collectively, the advancements made in these fields are quickly enhancing our capacity to genetically optimize the production of specific goods, including biofuels. Micro-algae have a variety of uses beyond biosensors, including the production of well-controlled size and shape nanoparticles **[17, 18]** and even biofuels to replace fossil fuels. **[19, 20]**. Utilizing microalgae in biotechnology also has the benefit of lowering the cost of biomass production by using wastewater phytoremediation **[20, 21]**.

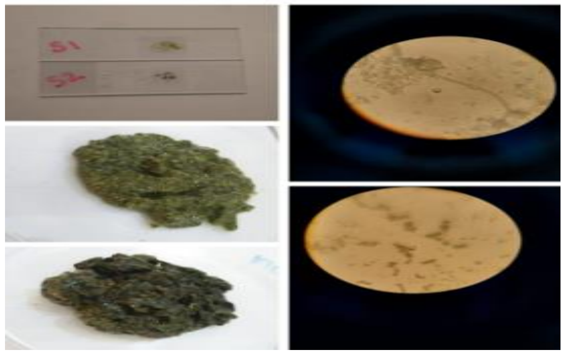

Figure 1: Microscopy of isolated Algal Samples

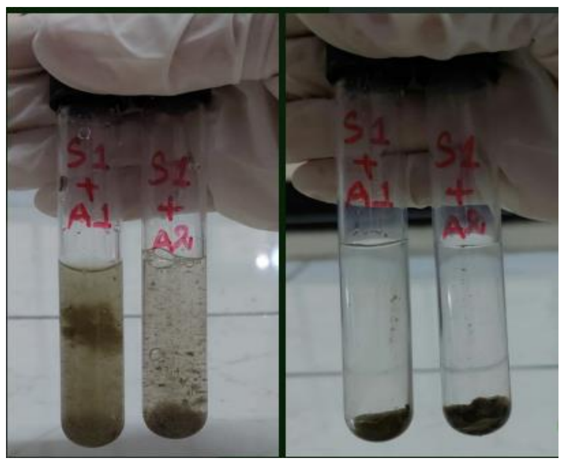

Figure 2: After the process of bioremediation

Table 1. Fluorescence production in a wastewater sample containing an algal species

Algal Sample	0 min	40 min	24 hours
Chlorella Vulgaris	14000	12000	8000

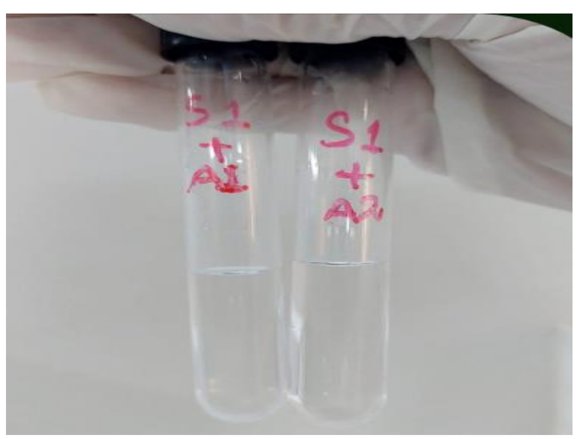

Figure 3: After the process of Nano- Filtration

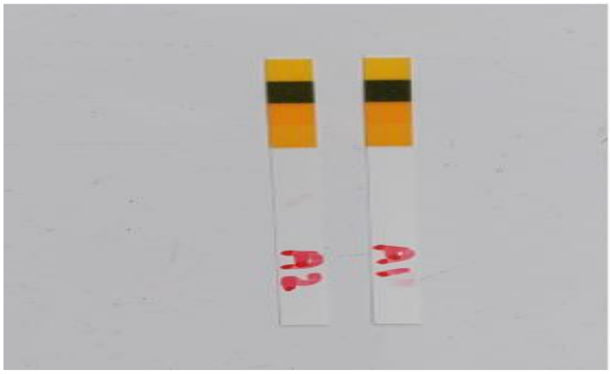

Figure 4: pH of treated water sample

Conclusion

As a result of this research, it was demonstrated that *Chlorella vulgaris* was highly effective at removing metal ions and dirt particles from our sample, as well as other toxins. Microalgae are efficient in removing emerging contaminants from wastewater samples and also proved efficient in detecting contaminants in samples when used as a biosensor. Thus, it is concluded that microalgae are effective for bioremediation and as a biosensor and that its byproducts can also be used to manufacture beneficial products.

Authors' contributions

Conceived and designed the experiments: SQZ Zaidi & T Malik Performed the experiments: SQZ Zaidi, AA Mirza & M Fatima, Analyzed the data: T Malik, Contributed reagents/ materials/ analysis tools: SQZ Zaidi, AA Mirza & M Fatima, Wrote the paper: SQZ Zaidi, AA Mirza & M Fatima.

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