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Microalgae-Based Low-Cost Bioremediation for Heavy Metal Removal in Decentralized Water Systems: Evaluation of Coelastrella sp. (MH923011)

Duha Zeki Al-Swefee, Ithar Kamil Al-Mayaly, Ahmed Saleem AL-Jumaili

Abstract: *The natural supplies of water remain a source of concern as a reliable source for safe drinking worldwide, mainly due to contamination caused by heavy metals such as Lead (Pb), Nickel (Ni), and Cadmium (Cd). In this study, we appraise the action of the microalgae called Coelastrella sp. (MH923011) as it represent cost effective source and viable solution for getting ride from the harmful effect cussed by the heavy metals. Different concentrations of Lead, Nickel, and Cadmium (10, 20, and 30) ppm were applied to evaluate the ability of Coelastrella sp. (MH923011) to remove them for removal by the action of microalgae. These heavy metals are obtained from the aqueous solution. Experimental treatments were conducted under controlled laboratory conditions at different metal concentrations and exposure periods. Algal growth was monitored by measuring optical density (O.D.) through the experiment. The results show a significant reduction in Lead, Nickel, and Cadmium concentrations in treated samples, accompanied by adaptive changes in microalgal growth. According to these findings, Coelastrella sp. shows the ability to perform a high tolerance rate and metal uptake. This research demonstrates that Coelastrella sp. can serve as a viable biological agent for heavy metal removal, with strong potential for application in community-level water treatment solutions in resource-constrained regions.*

Keywords: Microalgae, Coelastrella sp. (MH923011), Heavy metals, biosorption

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Introduction

Heavy metals can be defined as substances identified by their high electrical conductivity, malleability, and glitter that readily lose electrons to form cations. According to their locality's variation, the heavy metal compositions are differentiated, resulting in spatial variations of surrounding concentrations [1]. These elements are widely dispersed in the atmosphere as they are controlled by the properties of the metal and numerous environmental factors [2]. Heavy metals distinguish with a specific density greater than 5 g/cm^3, harming both living beings and the environment [3]. These elements (The Heavy metals) occur naturally in various habitats, characterized by ultimate features such as their density higher than water by approximately five times, and high atomic weight. Among these distributions in the environment, it led to wide benefits in medical approaches, various applications used in technologies, as well as human health beneficial treatment [4]. Heavy metals can be found mixed with impurities as a result of their naturally existing in the environment; thus, the requirements for specific technologies for quality improvement are applied, for example, the use of lime as a precipitation agent, ion exchange, and new technologies applications are indeed required to reduce the heavy metal concentrations to gain ecologically acceptable levels at affordable costs [5].

The culture of microalgae represents an attractive strategy for treating the wastewater; microalgae act to provide a tertiary biotreatment in addition to producing a valuable biomass. Both quandary and tertiary treatments can be replaced by the utilization of Microalgae, as these microorganisms use phosphorus and inorganic nitrogen as a source for their growth due to their ability to eliminate heavy metals [6]. microalgae had the ability for the bioremediation of wastewater and heavy metals through the processes of biosorption, bioaccumulation mechanisms [7and 8]. However, limited information is available regarding the ability of *Coelastrella* sp. to remove heavy metals, particularly lead, nickel, and cadmium. Therefore, the present study aims to evaluate the potential of microalga *Coelastrella* sp. (MH923011) to remove Pb, Ni, and Cd from aqueous solutions.

Materials and methods

Isolation of Coelastrella sp.(MH923011)

A specific strain of Microalgae (MH923011) was used throughout the whole experimental work. The strain was isolated from the Tigris River and recorded under No. MH923011 by Abed *et al*. [9].

Preparation and Sterilization of Culture Media

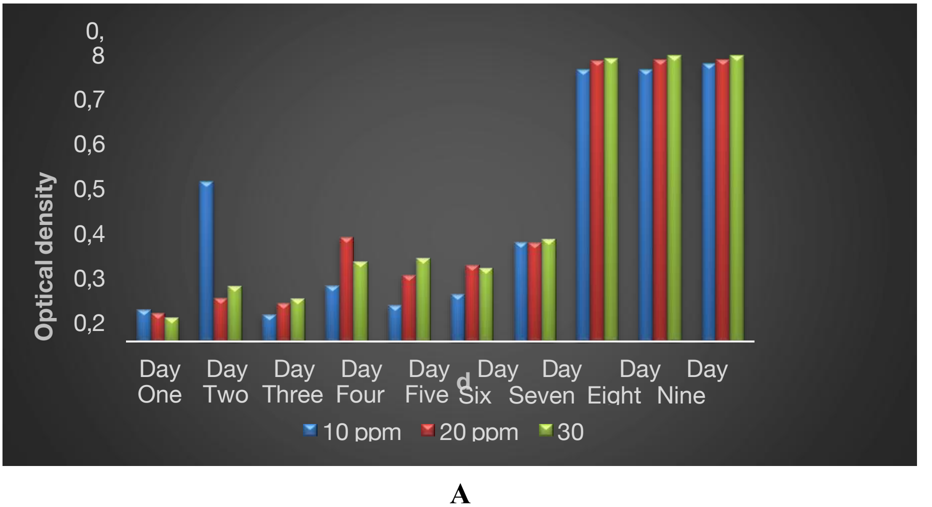
BG-11 was used as culture media, media prepared by using 1 L of D.W to dissolve 1.627 g of BG-11, pH value was adjusted to 7 by using either 0.1 N of NaOH or HCl. Autoclave was used for the media sterilization 121°C/1.5 bar of pressure for 15 minutes; this step is considered a critical action for the disposal of any microorganisms [10].

Preparation of Stock Solution

The following pure salts [Pb $(NO3)_2$, $NiCl_2$ $5H_2O$, and $Cd(NO3)_2$] were utilized for the preparation of a heavy metals stock solution. Each salt was dissolved in deionized D.W to gain a final concentration of 1000 ppm, and dark bottles were used for the storage. Heavy metal concentrations were calculated according to the following equation: $M_1V_1 = M_2V_2$where M1was the stock solution concentration, M_2 the required concentration, $V_1$the volume of the stock solution, and V_2 the volume of the solution at the required concentration. Three concentrations (10, 20, and 30 ppm) of each heavy metal were prepared.

Results and Discussions

The outcome from the experimental work showed that the growth of *Coelastrella* sp.(MH923011) was affected by the occurrence of heavy metals (Pb, Ni, and Cd) at different concentrations (10, 20, and 30 ppm) as shown in Figure 1. In general, algal growth decreased with increasing metal concentration, indicating a concentration-dependent inhibitory effect. Among the studied metals, optical density (O.D.) of Microalga *Coelastrell* MH923011 exposure to lead (Pb) showed the least inhibitory effect on algal growth, particularly at lower concentrations (10 ppm) after 10 days where optical density (O.D.) level was 0.328, whereas cadmium (Cd) exhibited reduction in growth rate at 20 and 30 ppm where O.D. level 0.088 and 0.083 respectively. While highest O.D. level of Nickel (Ni) at 30 ppm was 0.087. Heavy metal removal by microalgae primarily occurs via a two-stage process involving rapid extracellular biosorption followed by slower intracellular bioaccumulation. These mechanisms rely on the presence of functional groups on the algal cell wall and intracellular chelating compounds such as phytotherapies and glutathione [11]. This variation in growth response may be attributed to differences in metal toxicity, cellular uptake, and the ability of *Coelastrella sp.* to tolerate and detoxify specific heavy metals [7 and 8].



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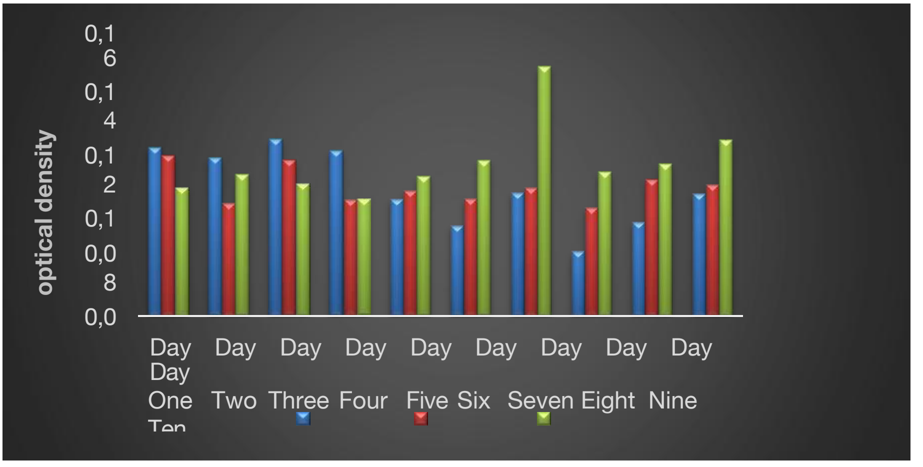

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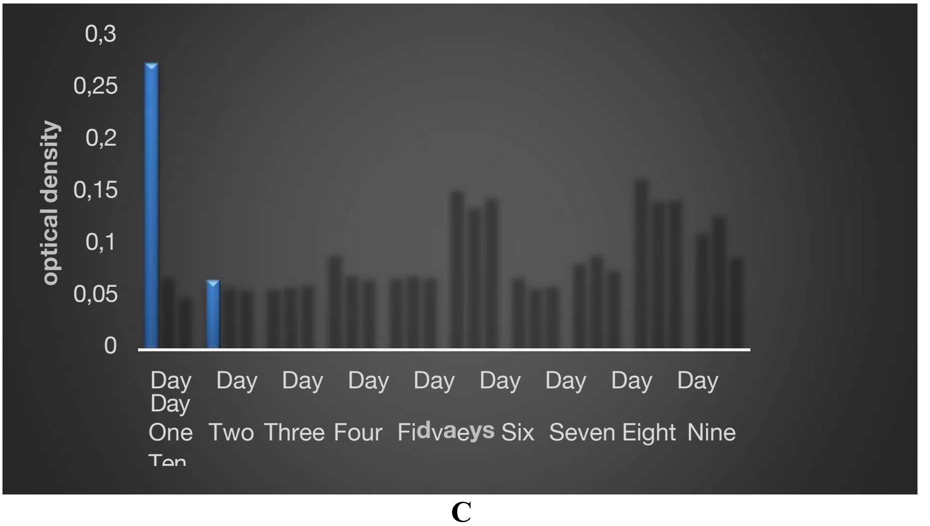

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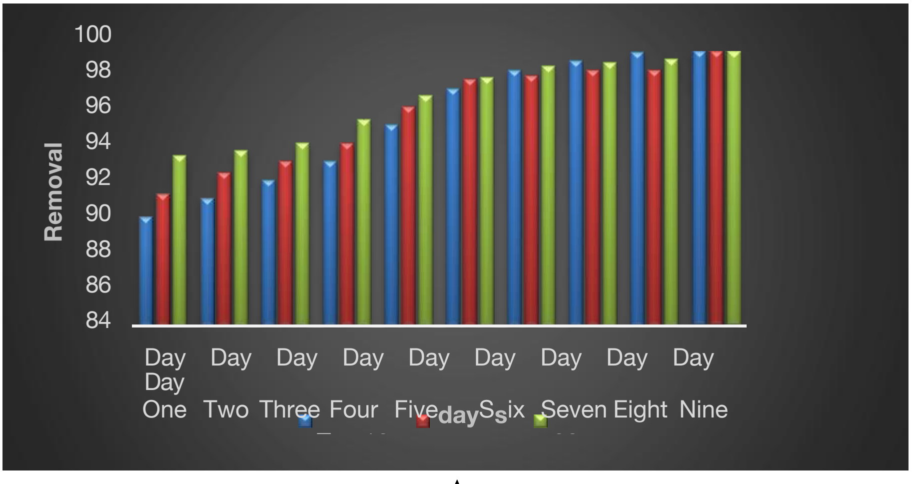
Figure 1: Optical density of Microalga *Coelastrell* MH923011 exposure to different concentrations, where A=Pb, B= Ni, and C= Cd.

The removal efficiency of Pb, Ni, and Cd by *Coelastrella sp.* at different concentrations was illustrated in Figure 2. The results showed that the microalga was capable of removing significant amounts of all tested heavy metals from the aqueous solutions. Lead (Pb) exhibited the highest removal efficiency among the three metals that was (99, 98, and 98.6) % at (10, 20, and 30) ppm respectively, followed cadmium (Cd) 93, 96.2, and 96.4% at 10, 20, and 30 ppm respectively by while nickel (Ni) showed the lowest removal percentage (68.4, 77.1, and 77) % at (10, 20, and 30) ppm. The removal efficiency generally increased with increasing initial metal concentration, suggesting that higher metal availability enhances biosorption and bioaccumulation processes [12 and 13]. The high removal capacity of

Coelastrella sp. can be explained by the presence of functional groups (such as carboxyl, hydroxyl, and phosphate groups) on the algal cell wall, which play an essential role in metal binding during the biosorption stage [14]. Subsequently, bioaccumulation mechanisms are the process by which metals may be transported into the cells. Heavy metal removal by microalgae through combined biosorption and bioaccumulation processes, which were reported by our findings as well as previous studies' indications [6 and 8].



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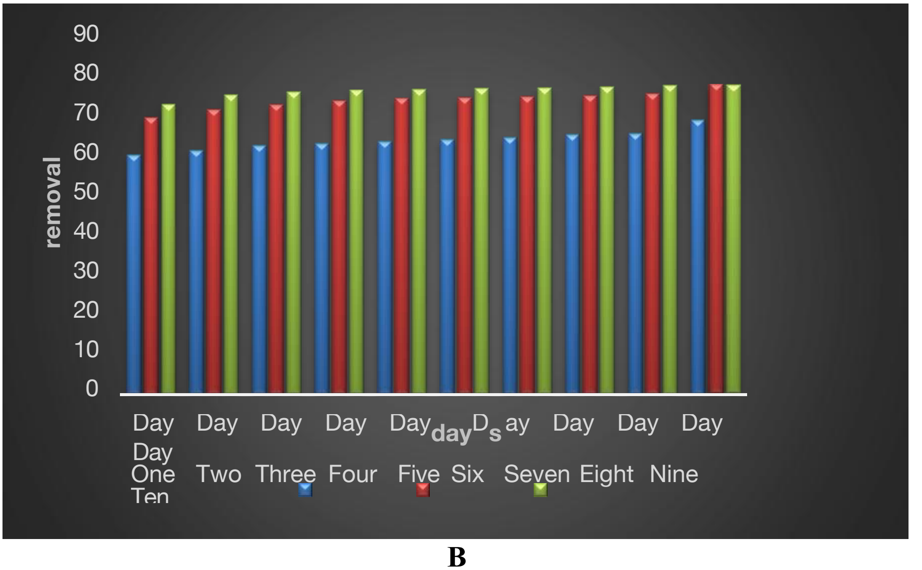

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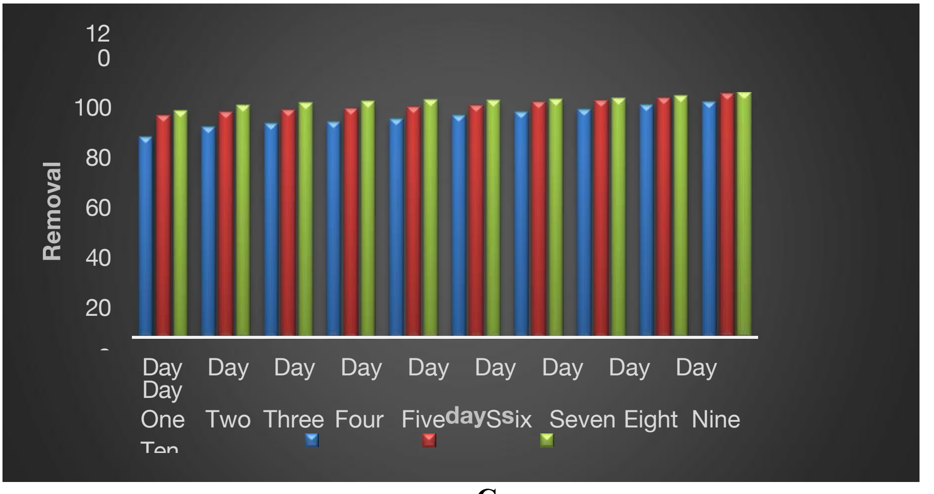

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Figure2: Heavy metal removal by microalga *Coelastrella* MH923011, where A= Pb, B= Ni, and C= Cd.

Cadmium exhibited the highest toxicity, leading to greater growth inhibition, with its strong ability to induce oxidative stress and disrupt cellular metabolism [15]. In contrast, the element lead showed lower toxicity and higher removal efficiency. The metal has a strong affinity for the binding sites in the cell surface and limited intracellular penetration. The genus *Coelastrella sp.* is characterized by metabolic flexibility and physiological ability to adapt and maintain growth under stress conditions produced by metals [16]. Similar observations have been reported in previous studies highlighting the resilience of microalgae and their effectiveness in heavy metal bioremediation [9]. Al-Mayaly *et al.* [17] studied the removal efficiency of zinc and copper by *Mougeotia* sp. and the results show high biosorption capacity of these filamentous green algae. Such findings support the results of the present study.

Conclusion

Our findings proved that microalgae *Coelastrella* sp.(MH923011) had the ability to remove the action of Lead, Nickel, and Cadmium to minimum levels in the aqueous solution. The results show a correlation between metal concentrations; the metal removal efficiency increases with increasing metal concentration. The highest levels of removal efficiency were shown by the Lead; in contrast, the ultimate inhibitory effect on algae growth was indicated by cadmium due to toxicity.

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