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BIOACCUMULATION AND BIOSORPTION STUDY OF HEAVY METALS REMOVAL BY CYANOBACTERIA *NOSTOC* SP.

Article Highlights

- The capacity for removing heavy metal ions by cyanobacteria *Nostoc* sp. was evaluated
- Parameter influence on metal removal (concentration of HMs, contact time) was explored
- Biosorption and bioaccumulation processes for metal ion uptake were compared
- The results established a high removal potential of the *Nostoc* sp. for toxic metal ions

Abstract

Nowadays, various industrial and urban activities result in discharging enormous quantities of various pollutants and their accumulation in the environment. Considering that heavy metals in wastewater are a serious threat to the environment and human health and that conventional methods for their removal are not highly efficient, the current study mainly focuses on estimating cyanobacterial capability to accumulate different heavy metals from water and comparing bioaccumulation and biosorption processes. Cyanobacteria Nostoc sp. was used, and five heavy metals were selected for this experiment (Cd^{2+}, Cu^{2+}, Pb^{2+}, Ni^{2+}, Zn^{2+}). Examined concentrations of HMs were 20 mg/dm^3, 80 mg/dm^3, and 200 mg/dm^3 for the bioaccumulation study, while 20 mg/dm^3 and 80 mg/dm^3 of each HMs were used for biosorption experiments. Living cells of Nostoc sp. have the highest affinity for Pb^{2+} (98.15%) and Cu^{2+} (95.14%) removal from the solution by bioaccumulation. During the biosorption process, dried biomass of Nostoc sp., besides Pb^{2+} (92.27%) and Cu^{2+} (96.00%), shows a high affinity for Cd^{2+} (91.00%) removal. Living cyanobacterial cells of Nostoc sp. could accumulate 82% of Zn, while dried biomass adsorbs 87% of Zn^{2+}. Although the highest bioaccumulation of Ni^{2+} was only 38% while using the biosorption process, it was significantly higher (63.80%). These results could provide a preliminary study for further investigation in the direction of the development of immobilized biosorbents which could be used for industrial effluent treatment.

Keywords: bioremediation, cyanobacteria, toxic metals uptake, wastewater.

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SCIENTIFIC PAPER

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During the last few decades, increased industrialization mineral exploitation, and intensive agricultural and urban activities resulted in exacerbated environmental contamination due to the release of an enormous quantity of various pollutants into the environment. Many of the major problems with environmental contamination with pollutants are related to water quality issues [1]. Climate changes will further deteriorate water pollution due to the higher water temperature, potential floods, droughts, etc. [1]. Among the wide diversity of pollutants affecting water resources, heavy metals (HMs) are particularly

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concerned, considering their strong toxicity, even at low amounts, due to their accumulative effects [2]. The comprehensive definition of 'heavy metals' is that they are naturally occurring metals having an atomic number higher than 20 and an atomic density greater than 5 g/cm^3 [3]. Some of them are required in low concentration by living organisms due to their important roles in metabolic processes, and in that case, they are called essential elements. However, at higher levels, those metals are very toxic and nonessential HMs, which are non-required even in trace amounts for living organisms. The considerable harmful impacts of HMs on human health and the environment are related to their persistence and tendency to accumulate in living forms due to their non-degradable properties [4]. Chronic exposure to HMs can affect the nervous, respiratory, and reproductive systems, the kidney, liver, and other vital organs [4,5]. Also, some HMs, besides being toxic, show cancerogenic effects; thus, they represent a serious threat to the human population [4,5]. Acute exposure can lead predominantly to the dysfunction of the gastrointestinal, heart, and nervous systems, even though symptoms connected with other organs can also occur [6].

Since environmental contamination by HMs is prevalently caused by anthropological activity, regulations and standards regarding the prevention and control of environmental pollution are became more restrictive in recent years. Regardless of the regulatory restriction, due to the hazardous effects on all living organisms, the imperative should be to limit the discharge of toxicants into the environment. Novel and advanced eco-friendly wastewater treatments are needed to prevent contamination of water resources and to meet stringent environmental regulations regarding industrial discharge limits for heavy and toxic metals. Additionally, while regulation forces it to treat, highly efficient and cost-effective wastewater treatments will enable it to treat and recover more water from the industry from being reused. Numerous treatment processes can remove HMs from wastewater [7]. Various materials have been proposed, including silica gel, activated carbons, cellulose nanomaterials, clay, different polymers, etc. [8–10]. Conventional physicochemical methods for heavy metal removal from polluted water include chemical precipitation, ion exchange, reverse osmosis, oxidation or reduction, filtration, flocculation, evaporation, and electrochemical treatment [11–13]. However, most of those techniques are very expensive and are not acceptable from an ecological aspect either. Namely, those methods release secondary pollutants which negatively affect soil fertility [14]. In addition, most conventional methods are ineffective for a lower concentration of HMs (less than 100 mg/dm^3) [13]. Increased environmental protection awareness has prompted the development of more convenient and eco-friendly technologies which would be suitable to remove pollutants to a level lower than defined by law. Additional advantages of these processes would be the eventual recovery and reuse of metals [15]. Biological methods are alternatives to physicochemical methods, where microorganisms and plants are used for remediation. Biological methods which rely on heavy metal microbe interaction are sustainable and promising remediation techniques that have proven to be very effective for HMs removal from wastewater and are considered environmentally friendly and cost-effective [16,17]. Additional advantages of biological methods are in situ application at the contaminated place, cost efficiency, sorbent regeneration ability, and eco-friendly [18]. The concept will be suited to the sustainable goals of the United Nations.

Biosorption and bioaccumulation are biological methods suitable for heavy metal removal from wastewater [19]. The difference between those two processes is that in the biosorption process, pollutants are bounded on the surface of the cell wall, while in bioaccumulation, they are additionally accumulated inside the cell [15]. Biosorption is a metabolically passive process that occurs naturally in living and dead cells. It is a complicated physicochemical process resembling physisorption, chemisorption, ion exchange, and microprecipitation, but with sorbent material of biological origin called biosorbent [15,18,20]. Based on this fact, it is evident that in comparison with the classical chemisorption process, which includes complexations (encompassing coordination and/or chelation) and chemical binding by various materials, biosorption is a broad umbrella term used for the removal of various materials due to the different attractive forces between the substrate and biosorbent [21]. On the other hand, bioaccumulation is an active metabolic process of pollutants uptake by living cells. In bioaccumulation, the first step is biosorption, and then pollutants are transported inside the cell and accumulated intracellularly through the cell metabolic cycle. This process is driven by energy consumption and only occurs in special biological cells.

Cyanobacteria are photosynthetic prokaryotes widely used in various bioremediation processes of HMs due to their significant biosorption and bioaccumulation abilities [22,23].

They can be found in various environments worldwide but usually in lakes, rivers, and seas. Due to their unique physiological adaptive properties, cyanobacteria can inhabit extreme places like deserts, the Arctic, hot springs, and metal-contaminated territory [24–26]. Cyanobacteria use various mechanisms to

cope with the toxic accumulations of HMs [23,24]. They can synthesize metal-binding proteins (MBPs). The largest group of MBPs are metallothioneins, capable of binding HMs with the thiol group of their cysteine amino acids. Synthesis of metallothioneins increases in response to elevated concentrations of certain metals. Besides, the redox machinery inside the cells, including enzymatic (catalase, peroxidase) and non-enzymatic (glutathione, carotenoids) components, help the cyanobacteria to tolerate HM-induced stress [24]. The biosorption capacity of cyanobacteria is correlated with the high number of functional groups on the cell's surface or around the cell [27–29]. Besides others, extracellular polysaccharides (EPSs) have the main role in the HMs biosorption process of cyanobacteria [23,30]. EPSs mainly comprise heteropolysaccharides with a strong anionic character, sulfate groups, various structural conformations, and amphiphilic behavior [31]. Due to the many negative charges on the external cell layers, EPS-producing cyanobacteria have been considered chelating agents for the positively charged HM ions [30]. By chelating, it is possible to remove positively charged heavy metal ions from water solutions. Besides, the production of EPSs increases as the adaptability of cyanobacteria to cope with harsh unfavorable growth conditions by forming a biofilm on the surfaces [32].

Despite the numerous reports on various metal removal from aqueous solutions by using cyanobacteria, most of the studies carried out have examined the removal of single metal and eventually multi-metals by bioaccumulation or biosorption [28,33,34]. Parallel evaluation of biosorption and bioaccumulation activity for multi-elements is also very poor and is limited to particular cyanobacteria cultures. Therefore, in this study, the utility of cyanobacteria culture *Nostoc* sp. in removing heavy metal ions from the water was examined to determine the potential of the examined culture for the bioremediation of polluted waters. Bioaccumulation and biosorption capacity of culture *Nostoc* sp. were compared for several HMs, including Pb, Cd, Cu, Zn, and Ni.

MATERIALS AND METHODS

Chemicals

All chemicals used throughout the experimental works were of analytical reagent grade if otherwise not specified (Merck, Darmstadt, Germany; Lach-Ner, Brno, Czech Republic; and Sigma Aldrich, St. Louis, MO, USA). The stock solution (1000 mg/dm^3) of each heavy metal used for bioaccumulation and biosorption study was prepared by dissolving an appropriate amount of the adequate salt ($Pb(NO_3)_2$, $CdCl_2{\cdot}2H_2O$, $CuSO_4{\cdot}5H_2O$, $ZnSO_4{\cdot}7H_2O$, and $NiCl_2{\cdot}6H_2O$) in doubly distilled water.

Cultivation of *Nostoc* sp.

Cyanobacterial culture *Nostoc* sp. (IRN 9B) was provided by the LAPER Laboratory, Faculty of Sciences, Department for Biology and Ecology, Novi Sad. Five cm^3 of living inoculum culture with a microbial concentration of 3 g/dm^3 was used to inoculate 0.5 dm^3 cultivation medium. The cyanobacteria were grown in a BG-11 medium [35]. The 30 days cyanobacterial cultures were used for all experiments, and microbial suspension concentration was kept constant at 0.2 g/dm^3 b subsequent dilution with a BG-11 medium. The cell concentration in the suspension was determined by the dry weight as a specific volume of cyanobacterial suspension, after being centrifuged and washed thoroughly with distilled water, was dried in an oven at 105 °C until constant weight. Static cultivation was performed under a light/dark cycle of 12/12 h with moderate light intensity at (25±1) °C. During the cultivation time, all vessels were manually shaken twice daily to avoid the aggregation and to prevent the cells' adherence to the vessel's wall. The position of the vessels was changed every third day to reduce the influence of light.

Before experiments, all laboratory glassware and plastic used in experiments were washed with dilute HNO_3 solution (1:1, v/v) to remove any impurity that may affect heavy metal adsorption, then rinsed with distilled and double-distilled water. Afterward, to prevent any contamination, all instruments and mediums were sterilized at 120 °C for 15 min to prevent contamination.

Bioaccumulation study

In a medium with cyanobacteria (after 30 days of cultivation), a defined volume of the stock solution of heavy metal was added in each vessel to obtain final concentrations of 20 mg/dm^3, 80 mg/dm^3, and 200 mg/dm^3. Prepared mediums rested for exactly 72 h, which was more than ample time for sorption equilibrium. Afterward, they were prepared for analysis of their HMs content. Experiments were done in three replicates for each metal and every concentration. A diluted stock solution of HMs by BG-11 medium at concentrations of 20 mg/dm^3, 80 mg/dm^3, and 200 mg/dm^3 without cyanobacteria were filtered, acidified with cc HCl and analyzed by atomic absorption spectrophotometry (AAS) to control the initial concentration of HMs on the resulting medium.

Additionally, for every group of samples, there were three controls without HMs. After 72 h of

bioaccumulation, 50 cm^3 of controls and all the samples were filtered using qualitative filter paper (Whatman No. 1, Whatman International, Maidstone, UK). Afterward, filtrates were acidified with cc HCl (*Suprapur*, Merck, Darmstadt, Germany) to the final acid concentration of 0.1 mol/dm^3. The concentration of metal was determined in acidified filtrates after eventual subsequent dilution.

Bioaccumulation was expressed as a percentage of accumulated metal compared to initial metal concentration (Eq. 1) as follows:

$$Bioaccumulation(\%) = \frac{C_i - C}{C_i} \cdot 100 \quad (1)$$

where C_i (mg/dm^3) is the initial concentration of added heavy metal, while C (mg/dm^3) is the residual concentration of metal ion after 3 days of bioaccumulation.

Biosorption study

The biomass was collected from the control samples (30 days cyanobacterial cultures) by using centrifugation at 3000 rpm for 10 minutes (MSE Harrier 15/80, Nuaillé, France). After that, cells were air-dried to constant weight and ground to powder using a pestle and mortar. The obtained biomass was kept in the polyethylene bottles in a dark place until used. The biosorption study was performed in a 250 cm^3 conical flask, where 40 mg of cyanobacterial dried biomass was in contact with 40 cm^3 of a solution of specific heavy metal. Examined concentrations of each heavy metal were 20 mg/dm^3 and 80 mg/dm^3. All experiments were done in three replicates for each heavy metal ion and both concentrations. Three control samples were without added biomass for every metal and both concentrations. The experiments were performed at a room temperature of (25±1) °C. Each sample was shaken on a magnetic stirrer at 150 rpm. After 30 minutes, 60 minutes, 90 minutes, and 120 minutes, aliquots of 5 cm^3 were taken and filtered through filter paper. Filtrates were acidified with *suprapur* cc HCl (final concentration 0.1 mol/dm^3). The concentration of metal was determined in acidified filtrates after eventual subsequent dilution.

Biosorption uptake of heavy metals expressed as the amount of metal ions adsorbed per specific amount of biosorbent [36] was calculated by the equation (2):

$$Q\left(\frac{mg}{g}\right) = \frac{V(C_i - C)}{m} \quad (2)$$

where Q (mg/g) is the metal uptake, V (dm^3) is the volume of solution, C_i (mg/dm^3) is the initial metal concentration, C (mg/dm^3) is the residual concentration of metal, and m (g) is the dry weight of biosorbent. Besides the biosorption ability of metal uptake per g of dry matter of biosorbent, the percentage of metal uptake from an initial metal concentration was also calculated.

Metal analysis

The examined HMs' concentration was determined in acidified filtrates and controls using an atomic absorption spectrophotometer ICE3000 (ThermoFisher, China). All parameters for AAS (wavelength, slit, flame stoichiometry) were set following the manufacturer's recommendation. Pb, Cd, Cu, and Zn stock solutions in 2% HNO_3 were purchased from CPA chem (Stara Zagora, Bulgaria), while the Ni stock solution was obtained from Merck (Darmstadt, Germany). The concentrations of certain metals were determined after filtrate dilutions to obtain an optimum concentration range for the atomic absorption spectrometric method. All analyses were performed in triplicate, and the calibration curves used were linear (R = 0.998).

All measurements were performed in appropriate repetitions, as mentioned in the manuscript's main text. Obtained data were summarized, and the results were evaluated with Microsoft Office Excel software (version 2007; Microsoft Corp, Redmond, WA, USA). Standard deviation (StDev) was calculated for all types of experiments based on three repeated results. The calibration curves for AAS were treated by linear regression, and the corresponding results were reported with a 95% confidence level.

RESULTS AND DISCUSSION

Cyanobacteria *Nostoc* sp. was observed for individual bioremediation of Pb^{2+}, Cd^{2+}, Cu^{2+}, Zn^{2+}, and Ni^{2+} from water. The bioaccumulation results after 3 days for all examined metal ions are shown in Figure 1.

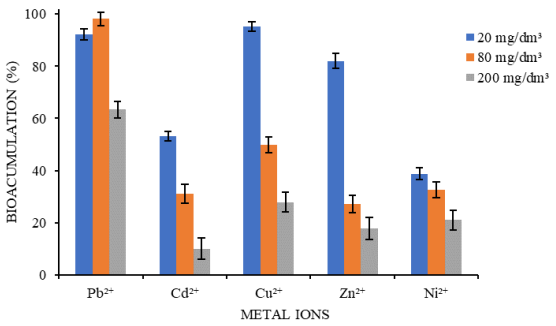

Figure 1. Bioaccumulation of heavy metals in solutions with living cells of Nostoc sp. at 20 mg/dm^3, 80 mg/dm^3 , and 200 mg/dm^3 of heavy metal ions (bars represent the standard deviation).

From Figure 1, it is evident that after 3 days, *Nostoc* sp. accumulated a great amount of Cu^{2+}, Zn^{2+}, and Pb^{2+}. At lower initial concentrations of Cu^{2+} and Zn^{2+} metal ions, the bioaccumulation ability of examined cyanobacteria was more efficient. *Nostoc* sp. removed Cu^{2+} ions up to 95.14% and Zn^{2+} ions up to 82% at a concentration of 20 mg/dm^3 Cu^{2+} and Zn^{2+}, respectively. At an initial concentration of 20 mg/dm^3 Pb^{2+}, *Nostoc* sp. accumulated 92.18% of this heavy metal ion, while bioaccumulation of even 98.15% was obtained when the initial concentration of Pb^{2+} was 80 mg/dm^3. The highest bioaccumulation of Cd^{2+} was 53.27% at a concentration of 20 mg/dm^3, while for the same concentration of Zn^{2+}, the bioaccumulation power of *Nostoc* sp. was 82.06%. As shown in Figure 1, the bioaccumulation efficiency of *Nostoc* sp. for Ni^{2+} removal was the smallest compared to the other HMs. Only 38.75% of Ni^{2+} was removed by *Nostoc* sp. during 3 days of bioaccumulation. From Figure 1, it is evident that metal concentrations significantly influence the biosorption metal uptake. The highest bioaccumulation of Cd^{2+}, Cu^{2+}, Zn^{2+}, and Ni^{2+} was achieved at an initial concentration of 20 mg/dm^3, except for Pb^{2+}, where the highest bioaccumulation was achieved at a concentration of 80 mg/dm^3 (98.15%). It can be explained that during the bioaccumulation, a saturation of *Nostoc* sp. capacity for HMs removal was reached in the case of higher concentrations of Cd^{2+}, Cu^{2+}, Zn^{2+}, and Ni^{2+}, as well as for the highest concentration of Pb^{2+} (200 mg/dm^3) probably due to the disrupted diffusion of the metal ions into the liquid phase. Besides, higher HM concentrations could provoke damage to the cell walls of living cells, so they might lose their binding abilities resulting in remarkably lower bioaccumulation capacity uptake. These results suggest that bioaccumulation of heavy metal ions by *Nostoc* sp. was a very effective remediation process, especially for lower concentrations of metal contaminants.

To calculate the amounts of metal ions adsorbed per specific amount of biosorbent (*Q, mg/g*), residual metal concentrations were measured after 30 minutes, 60 minutes, 90 minutes, and 120 minutes of contact time between metal solution and dried cyanobacterial biomass for all five studied metals. All those results are presented in Table 1. In addition, the dependence of the metal uptake (in %) on the contact time is presented in Figure 2 for all five heavy metal ions.

Table 1. Biosorption uptake of Pb^{2+}, Cd^{2+}, Cu^{2+}, Zn^{2+}, and Ni^{2+} (mg/g) by biomass of Nostoc sp.

Metal ions	*Ci* (mg/dm^3)	$Q_{30\ min}$	$Q_{60\ min}$	$Q_{90\ min}$	$Q_{120\ min}$
		(mg/g)[a]			
Pb	20	12.01±0.98	11.7±1.22	11.56±0.87	11.52±1.05
	80	73.82±3.54	72.6±4.01	71.61±2.82	73.74±4.24
Cd	20	16.6±1.96	17.45±1.57	17.55±1.35	18.2±0.99
	80	70.95±4.54	70.4±3.89	71.95±3.56	64.6±4.53
Cu	20	19.32±2.02	17.89±2.39	17.25±1.80	18.00±1.45
	80	53.1±4.15	60.55±3.87	51.15±3.21	49.05±1.99
Zn	20	16.55±1.56	17.40±0.65	17.35±0.85	16.95±1.20
	80	30.30±3.28	29.00±3.08	30.25±2.22	30.8±2.09
Ni	20	11.84±0.99	11.56±1.76	12.76±1.63	12.32±1.33
	80	22.36±2.56	23.12±1.93	23.44±3.00	19.20±2.15

[a]mean±2StDev, n=3

Biosorption of heavy metals by examined biosorbent depended on the initial concentration and properties of metal ions for most of examined HMs. In the case of Cd^{2+}, initial concentrations of metals did not significantly affect the biosorption uptake of metal. Contact time did not contribute significantly to the Pb^{2+}, Cd^{2+}, Zn^{2+}, and Ni^{2+} uptake by *Nostoc* sp. It can be explained that for all those metals, equilibria between adsorbed and metal remaining in the water were achieved after 30 minutes. Additionally, it can be noticed that the higher biosorption for all the metals was at lower concentrations of 20 mg/dm^{3,} probably as a consequence of cell surface saturation at a higher concentration of HM ions, except for Pb^{2+}, whose biosorption was higher at 80 mg/dm^3 (92.17%).

Biomass of *Nostoc* sp. removed 91% of Cd^{2+} after 120 minutes of contact time, corresponding to the biosorption uptake of 18.2 mg/g of dry biosorbent. Even 96% of Cu^{2+} is removed after the first 30 minutes of the experiment, which respects the biosorption uptake of 19.32 mg/g. Also, there were significant results for Pb^{2+} removal. After only 30 minutes of the experiment, dried *Nostoc* sp. biomass removed up to 73.82 mg/g of Pb^{2+}, which was 92.27%. The highest biosorption for Ni^{2+} was 12.76 mg/g (63.80%) after 90 minutes. Using the biosorption process by dried cyanobacterial biomass sorbent, the uptake of Zn^{2+} was 17.40 mg/g (87%) after 60 minutes of contact time.

Bioaccumulation and biosorption studies evidenced the capability of *Nostoc* sp. for HMs removal. Bioaccumulation is likely to be most effective for Pb^{2+} and Cu^{2+} removal from wastewater, while the biosorption process was very effective for removing Pb^{2+} and Cu^{2+}, Cd^{2+}, and Zn^{2+}. Also, it is worth noting that, compared to the bioaccumulation process, which lasted longer, the biosorption process was more

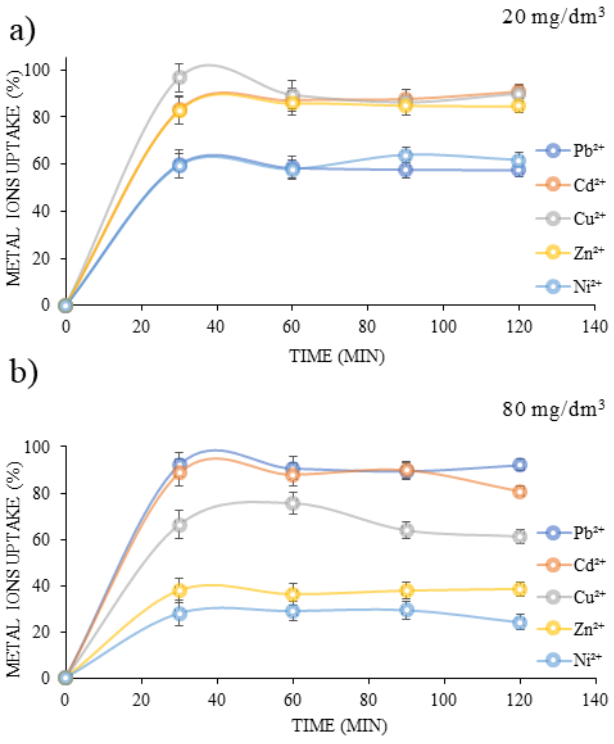

Figure 2. Results of metal ions uptake (%) by dead biomass of Nostoc sp. from water containing HMs ions as a function of contact time. a) 20 mg/dm^3 and b) 80 mg/dm^3 of metal ions (bars represent the standard deviation).

favorable for removing the studied metal ions due to the very short time. Namely, after 30 minutes, the biosorbent from *Nostoc* sp. could remove more than 90% of Pb^{2+} and Cu^{2+}. On the other hand, results showed that *Nostoc* sp. is not so efficient for decontaminating water resources from Ni^{2+}. It can be explained by the fact for Ni^{2+} removal, either by bioaccumulation or biosorption, initial concentrations were too high.

Many authors reported similar results about heavy metal removal by culture *Nostoc* sp. El-Naggar *et al.* reported that *Nostoc muscorum* removes up to 88% of Cu^{2+}, 82% of Cd^{2+}, 49% of Zn^{2+}, and 44% of Ni^{2+} [37]. Micheletti *et al.* also reported a high affinity of *Nostoc* PCC7936 for Cu^{2+} removal [38]. El-Sheekh *et al.* found that *N. muscorum* accumulates up to 81.8% of Cu^{2+}, 100% of Pb^{2+}, and 33.7% of Co^{2+} [39]. Goswami *et al.* reported that *N. muscorum* accumulates 66% of Zn^{2+} and 71% of Cu^{2+} for 24 h of contact time between cyanobacterial cells and metal solution [40]. Also, Roy *et al.* presented great results of *N. muscorum's* capability to accumulate heavy metals. After 60 h of bioaccumulation, *N. muscorum* removed 96.3% of Pb^{2+}, 96.42% of Cu^{2+}, 80.04% of Cd^{2+}, and 71.3% of Zn^{2+} [41]. Hazarika *et al.* found that *N. muscorum* removed 82% of Cd^{2+} after 30 h at an initial concentration of 5 mg/dm^3 and that accumulation at lower initial concentrations of Cd^{2+} was more efficient [42]. Based on the presented results in this work, it is evident that bioaccumulation of observed HMs is more efficient if the initial concentration is lower. Also, in the biosorption experiment, the highest biosorption capacities were at the lowest examined concentration for most metals. It indicated that bioaccumulation and biosorption of HMs by *Nostoc* sp. can be used to remove metal pollutants from wastewater, especially considering that conventional methods for HMs removal from wastewater are ineffective for a lower concentration of HMs.

CONCLUSION

The results of the present study showed that cyanobacteria *Nostoc* sp. possess a high capacity for heavy metal removal from aqueous solution. Both of the used processes, bioaccumulation and biosorption, have shown good uptake capacities for most of the tested heavy metals. Somewhat better HMs uptake from the water was obtained using dead cell *Nostoc* sp. Based on obtained results, it is worth stressing that cyanobacteria represent suitable and promising biosorbents for heavy metal removal from aqueous solutions, which makes them a good candidate as an alternative to conventional methods used for water purification. In addition, biosorption and bioaccumulation techniques are relatively cheap and environmentally friendly bioremediation and wastewater purification processes. Commercial exploitation and application of *Nostoc* sp. cyanobacteria require further investigation in modeling and testing immobilized biomass with industrial effluents.

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NAUČNI RAD

ISPITIVANJE PROCESA BIOSORPCIJE I BIOAKUMULACIJE TEŠKIH METALA PRIMENOM CIJANOBAKTERIJA *NOSTOC* SP.

U današnje vreme različite industrijske i urbane aktivnosti dovode do ispuštanja ogromnih količina raznih zagađujućih materija i njihovog akumuliranja u životnu sredinu. S obzirom da prisustvo teških metala u otpadnoj vodi predstavlja ozbiljan problem po životnu sredinu i ljudsko zdravlje, a i da konvencionalne metode za njihovo uklanjanje nisu efikasne, cilj ovog rada je procena sposobnosti cijanobakterija da uklanjaju različite teške metale iz vode procesima bioakumulacije. i biosorpcije. U ove svrhe su korišćene cianobacterije Nostoc sp. i pet teških metala (Cd^{2+}, Cu^{2+}, Pb^{2+}, Ni^{2+}, Zn^{2+}). Ispitivane koncentracije teških metala su bile 20 mg/dm^3, 80 mg/dm^3 i 200 mg/dm^3 za proces bioakumulacije, dok je za eksperimente biosorpcije korišćeno 20 mg/dm^3 i 80 mg/dm^3 svakog pojedinačnog metala. Žive ćelije Nostoc sp. pokazale su najveći afinitet za uklanjanje Pb^{2+} (98,15%) i Cu^{2+} (95,14%) iz rastvora bioakumulacijom. Tokom procesa biosorpcije, osušena biomasa Nostoc sp., pored Pb^{2+} (92,27%) i Cu^{2+} (96,00%), pokazala je visok afinitet pri uklanjanju Cd^{2+} (91,00%). Žive cijanobakterijske ćelije Nostoc sp. bile su sposobne da akumuliraju 82% Zn^{2+}, dok je osušena biomasa adsorbovala 87% Zn^{2+}. Najveća bioakumulacija Ni^{2+} iznosila je samo 38%, dok je primenom procesa biosorpcije uklanjanje nikla bilo značajno veće (63,80%). Ovi rezultati bi mogli da pruže preliminarnu studiju za dalja istraživanja u pravcu razvoja imobilizovanih biosorbenata koji bi se koristiti za prečišćavanje industrijskih otpadnih voda.

Ključne reči: bioremedijacija, cijanobakterije, teški metali, otpadne vode.