ANALYSIS OF THE BIOLOGICAL ADSORPTION CAPABILITIES OF CHROMIUM BY AZOLLA CAROLINIANA

Sh. Azimov
Tashkent State Technical University named after Islam Karimov
E. Egamberdiev
Tashkent State Technical University named after Islam Karimov
S. Turabdajanov
Tashkent State Technical University named after Islam Karimov

Abstract. This article investigates the potential of the aquatic fern Azolla caroliniana for the biological treatment of chromium (Cr)-contaminated wastewater. During the study, the growth dynamics, viability, and biosorption capacity of Azolla caroliniana under different chromium concentrations were examined. The results showed that Azolla caroliniana maintained its viability at chromium concentrations of up to 3 mg/L and was able to assimilate a significant amount of chromium. Experiments were conducted over intervals of 3, 7, 10, 14, and 21 days, with the maximum biosorption capacity of the plant observed between 14 and 21 days. The findings indicate that Azolla caroliniana is a promising bioremediation agent for the biological treatment of wastewater contaminated with heavy metals.

Keywords: Azolla caroliniana, bioremediation, biosorption, chromium, wastewater, heavy metals, aquatic plants, ecological purification, phytoremediation.

Аннотация. В данной статье исследуется потенциал водного папоротника Azolla caroliniana для биологической очистки сточных вод, загрязнённых хромом (Cr). В ходе исследования были изучены динамика роста, жизнеспособность и биосорбционная способность Azolla caroliniana при различных концентрациях хрома. Результаты показали, что Azolla caroliniana сохраняет жизнеспособность при концентрации хрома до 3 мг/л и способна аккумулировать значительное количество данного металла. Эксперименты проводились в течение 3, 7, 10, 14 и 21 суток, при этом максимальная биосорбционная способность растения наблюдалась в интервале от 14 до 21 суток. Полученные результаты свидетельствуют о том, что Azolla caroliniana является перспективным агентом биоремедиации для биологической очистки сточных вод, загрязнённых тяжёлыми металлами.

Ключевые слова: Azolla caroliniana, биоремедиация, биосорбция, хром, сточные воды, тяжёлые металлы, водные растения, экологическая очистка, фиторемедиация.

ISSN 3030-3907

Annotatsiya. Ushbu maqolada xrom (Cr) bilan ifloslangan oqava suvlarni biologik tozalashda Azolla caroliniana suv paporotnigining imkoniyatlari o‘rganilgan. Tadqiqot jarayonida turli xrom konsentratsiyalarida Azolla caroliniana ning o‘sish dinamikasi, hayotiyligi va biosorbsiya qobiliyati tahlil qilindi. Natijalar shuni ko‘rsatdiki, Azolla caroliniana xromning 3 mg/L gacha bo‘lgan konsentratsiyasida hayotiyligini saqlab qoladi va xromni sezilarli miqdorda o‘zlashtira oladi. Tajribalar 3, 7, 10, 14 va 21 kun oralig‘ida o‘tkazilib, o‘simlikning maksimal biosorbsiya qobiliyati 14–21 kun oralig‘ida kuzatildi. Olingan natijalar Azolla caroliniana ni og‘ir metallar bilan ifloslangan oqava suvlarni biologik tozalashda istiqbolli bioremediatsiya agenti sifatida qo‘llash mumkinligini ko‘rsatadi.

Kalit so‘zlar: Azolla caroliniana, bioremediatsiya, biosorbsiya, xrom, oqava suvlar, og‘ir metallar, suv o‘simliklari, ekologik tozalash, fitoremediatsiya.

INTRODUCTION.

Today, as a result of rapid industrial development, environmental pollution—especially the contamination of water resources with heavy metal–laden wastewater—has become one of the most pressing global ecological problems. Wastewater discharged from the leather industry, electroplating facilities, metal-processing plants, and thermal power stations often contains high concentrations of toxic elements such as chromium, posing serious threats to aquatic ecosystems. The high toxicity of chromium to living organisms, its long-term persistence in aquatic environments, and its tendency to bioaccumulate disrupt ecological balance.

Conventional physico-chemical treatment methods are characterized by high costs, the generation of secondary waste, and limited environmental safety. Therefore, in recent years, increasing attention has been directed toward biological treatment approaches, particularly technologies based on aquatic plants. Aquatic plants are capable of absorbing and accumulating heavy metals through their cell walls, a process known as biosorption.

Azolla caroliniana is a higher aquatic plant distinguished by its rapid growth, adaptability to unfavorable conditions, and nitrogen-fixation ability. Investigating the potential of this plant to assimilate heavy metals, including chromium, is of great importance for the development of environmentally safe and economically efficient wastewater treatment technologies.

The main objective of the present study is to determine the effectiveness of Azolla caroliniana in the biological treatment of chromium-contaminated wastewater and to evaluate its biosorption potential.

ISSN 3030-3907

Globally, the large volumes of wastewater containing harmful chemical substances generated by various industrial sectors give rise to serious environmental challenges. Biological wastewater treatment plays a crucial role in maintaining the stability of technogenic ecosystems. In particular, the purification of wastewater contaminated with hazardous chemicals using higher aquatic plants is of paramount importance from the standpoint of ecology and environmental protection. Wastewater discharged from leather-processing enterprises, paper mills, coal mines, and thermal power plants is especially dangerous for aquatic ecosystems due to its chromium content.

Worldwide, scientific research is being conducted to address severe environmental problems arising from the incomplete removal of harmful chemical substances from wastewater produced by leather-processing industries. In this context, special attention is being paid to determining the toxic properties of chromium in wastewater, its widespread use as a key component in electroplating, leather processing, and metal preparation and polishing, as well as to improving biological treatment methods for wastewater that has been treated by physico-chemical methods. Moreover, the generation of large quantities of sulfites, ammonium nitrogen, and protein compounds in leather-processing enterprises leads to drastic changes in ecosystems.

In our republic, particularly since gaining independence, significant scientific progress has been achieved in stabilizing the ecological situation, ensuring rational use of natural resources and available water reserves, widely implementing innovative water-saving technologies, protecting water resources from various types of pollution, and preventing human exposure to harmful substances.

MATERIALS AND METHODS. This study was aimed at evaluating the biosorption potential of Azolla caroliniana for the biological treatment of chromium (Cr)-contaminated wastewater. The experiments were conducted under laboratory conditions using an aqueous medium artificially contaminated with chromium. The initial chromium concentration in the experimental medium averaged 4.87 mg/L. As the research object, an adapted culture of Azolla caroliniana that maintained viability at chromium concentrations of up to 3 mg/L was used. For each experimental variant, the initial planting density was set at 100 g of biomass per 1 m^2. The experiments were carried out in five variants with three replicates each. Observations were performed at intervals of 3, 7, 10, 14, and 21 days. At each time point, the chromium concentration in the nutrient medium was determined, and changes in plant biomass and external morphological characteristics were recorded. Chromium content was measured using standard

ISSN 3030-3907

chemical analysis methods. The obtained data were statistically processed, and mean values and deviations were calculated.

RESULTS AND DISCUSSION. In the experiments, an Azolla caroliniana culture that maintained viability under the influence of 3 mg/L chromium—despite a sharp decrease in biomass accumulation and nitrogen-fixation activity—was selected as the experimental object.

To ensure methodological accuracy, all experimental variants were artificially contaminated with chromium, and the degree of chromium adsorption by the study object was investigated. According to the results, the chromium concentration in wastewater with an initial average value of 4.87 mg/L decreased to 4.34 mg/L on day 3 of cultivation, 3.81 mg/L on day 7, 3.34 mg/L on day 10, and 2.34 mg/L on day 14.

During the experiments, the average chromium concentration reached 2.27 mg/L. Based on the obtained results (Figure 1, Table 1), it was determined that the Azolla culture exhibiting viability at a chromium concentration of 3.0 mg/L contained 1.82 mg/L of chromium on the third day of cultivation, corresponding to a chromium uptake of 0.36 mg/g relative to the total chromium content.

In Variant 1, the chromium concentration in the nutrient medium with an initial value of 2.18 mg/L decreased to 1.82 mg/L by the third day of cultivation, and the chromium uptake capacity of Azolla was observed to be 0.36 mg/g.

In Variant 2, where the initial chromium concentration in the nutrient medium was 2.43 mg/L, the chromium content decreased to 2.11 mg/L on the third day of cultivation, and the chromium uptake capacity of the Azolla culture was recorded as 0.32 mg/g.

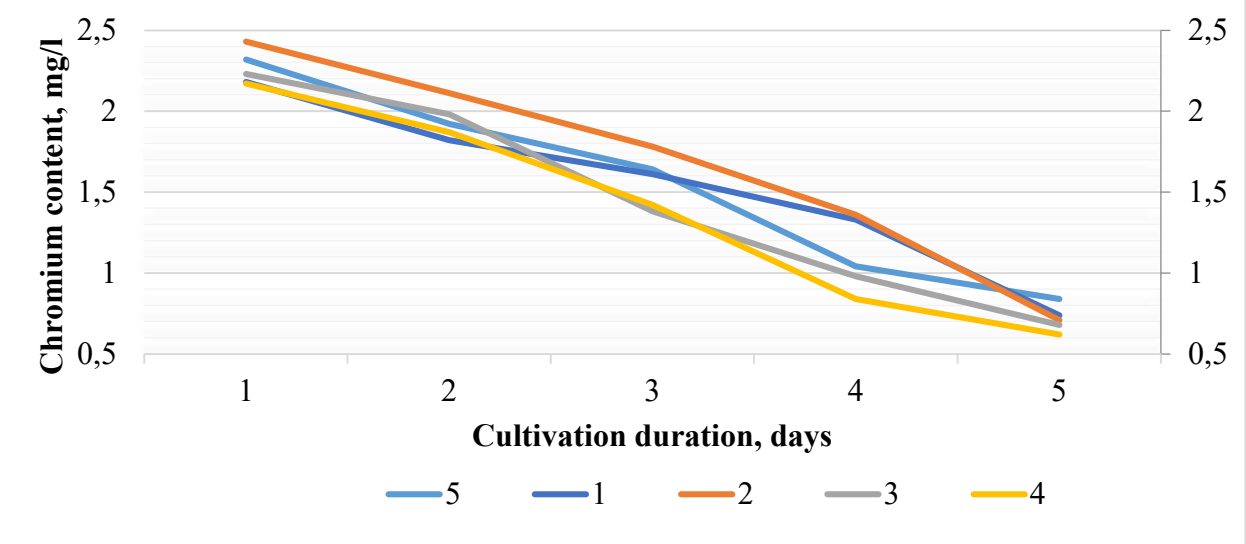


Figure 1. Chromium uptake by Azolla from wastewater.

Here is the accurate scientific English translation of your text, keeping the journal-style tone and terminology consistent with the previous sections:

ISSN 3030-3907

In Variant 3, where the initial chromium concentration in the nutrient medium was 2.23 mg/L, the chromium content decreased to 1.98 mg/L on the third day of cultivation, and the chromium uptake capacity of Azolla was determined to be 0.25 mg/g.

In Variant 4, the nutrient medium initially contained 2.17 mg/L of chromium, which decreased to 1.87 mg/L by the third day of cultivation, and a chromium uptake capacity of 0.30 mg/g was observed.

In Variant 5, with an initial chromium concentration of 2.32 mg/L in the nutrient medium, the chromium content decreased to 1.92 mg/L on the third day of cultivation, and the chromium uptake capacity of Azolla was found to be 0.40 mg/g.

Overall, across all variants, when the average chromium concentration in the nutrient medium was 2.27 mg/L and the initial planting density of the Azolla culture was 100 g per 1 m², the average chromium uptake capacity on the third day of cultivation was determined to be 0.36 mg/g.

During the experiments, on the seventh day of cultivation, when the average chromium concentration in the nutrient medium was 1.57 mg/L, the average chromium uptake capacities of Azolla in Variants 1–5 were 0.56 mg/g, 0.45 mg/g, 0.85 mg/g, and 0.75 mg/g, respectively, with an overall average of 0.70 mg/g across all variants.

Table 1

Chromium uptake capacity of Azolla caroliniana in the nutrient medium (W).

Experience options	Initial chromium level, mg/l	Chromium uptake in wastewater over days, mg/l				
		3	7	10	14	21
1	2,18±0,12	1,82±0,14	1,61±0,22	1,33±,017	0,74±0,22	0,73±0,27
2	2,43±0,23	2,11±0,32	1,78±0,33	1,36±0,27	0,71±0,19	0,84±0,32
3	2,23±0,31	1,98±0,17	1,38±0,18	0,98±0,09	0,68±0,42	0,70±0,12
4	2,17±0,11	1,87±0,43	1,42±0,11	0,84±0,19	0,62±0,27	0,62±0,33
5	2,32±0,19	1,92±0,21	1,64±0,44	1,04±0,38	0,84±0,22	0,84±0,29
Average	2,27±0,27	1,94±0,11	1,57±0,09	1,11±0,32	0,72±0,17	0,75±0,44

ISSN 3030-3907

Analysis of the experimental results showed that the difference between the average chromium uptake on the third and seventh days of cultivation increased from 0.33 mg/g to 0.70 mg/g. It was observed that as the biomass of Azolla increased, the chromium uptake capacity also increased dynamically.

During the experiments, on the tenth day of cultivation, when the chromium concentration in the nutrient medium was 1.11 mg/L, chromium uptake by Azolla in Variants 1–5 increased to 0.85 mg/g, 1.07 mg/g, 1.25 mg/g, 1.33 mg/g, and 1.28 mg/g, respectively. The average chromium uptake capacity across all variants was 1.15 mg/g.

When these results were compared with those obtained on the third day of cultivation, an increase from 0.33 mg/g to 1.15 mg/g was observed. Compared with the seventh day, chromium uptake increased by 0.45 mg/g. Thus, the analysis indicates a continued dynamic increase in chromium uptake by the tenth day relative to the initial cultivation period.

On the fourteenth day of cultivation, in a nutrient medium containing an average chromium concentration of 0.72 mg/L, chromium uptake by the Azolla culture in Variants 1–5 reached 1.44 mg/g, 1.72 mg/g, 1.55 mg/g, 1.55 mg/g, and 1.48 mg/g, respectively. The average chromium uptake capacity was determined to be 1.54 mg/g.

Compared with the third day of cultivation, chromium uptake increased by 1.21 mg/g; compared with the seventh day, by 0.84 mg/g; and compared with the tenth day, by 0.39 mg/g. These results further confirm the presence of a dynamic increasing trend in chromium uptake relative to the early cultivation stages.

During observations, particularly on the fourteenth and sixteenth days of cultivation, biomass degradation resembling leaf necrosis was recorded in Azolla cultures across Variants 1–5 at rates of 12.6 ± 0.17%, 23 ± 0.09%, 17.08 ± 0.13%, 16.24 ± 0.40%, and 8.9 ± 0.06%, respectively.

On the twenty-first day of cultivation, when the chromium concentration in the nutrient medium was 0.71 mg/L, chromium uptake by Azolla in Variants 1–5 was recorded as 1.45 mg/g, 1.59 mg/g, 1.19 mg/g, 1.53 mg/g, and 1.55 mg/g, respectively, with an average chromium uptake capacity of 1.52 mg/g. Comparative analysis showed no further dynamic increase in chromium uptake on day 21 compared to day 14, indicating that the maximum chromium uptake capacity of Azolla cultures reached approximately 1.52 mg/g.

Therefore, in the biological treatment of chromium-contaminated wastewater using Azolla cultures, periodic renewal of plant biomass is of critical importance to maintain high treatment efficiency.

ISSN 3030-3907

Conclusion. The results of the conducted study demonstrated that Azolla caroliniana exhibits high efficiency in the biological treatment of chromium-contaminated wastewater. Throughout the experiments, the plant showed the ability to adapt to chromium concentrations of up to 3 mg/L, maintain viability, and accumulate significant amounts of chromium in its biomass. The findings revealed that the biosorption capacity of Azolla increased with prolonged cultivation time and reached its maximum during the 14–21 day period. At the same time, it was determined that if plant biomass is not renewed after a certain period, necrotic symptoms begin to appear, indicating the necessity of periodic biomass replacement. The obtained scientific results provide a basis for the development of environmentally friendly, economically efficient, and sustainable bioremediation technologies based on Azolla caroliniana. This approach can be recommended as a promising method for the removal of heavy metals from industrial wastewater.

REFERENCES

1. Aravind P., Prasad MNV., Malec P., Waloszek A., Strzałka K. 2009. Zinc protects Ceratophyllum demersum L. (free-floating hydrophyte) against reactive oxygen species induced by cadmium. J Trace Elem Med Biol 23:50–60.
2. Arimoro, F., Chukwujindu, I. &Osiobe, O. 2008 Effects ofindustrial waste water on the physical and chemicalcharacteristics of a tropical coastal river. Research Journal ofEnvironmental Sciences 2 (3), 209–220.
3. Arora, A., A. Sood, and P.K. Singh. 2004. Hyperaccumulation of cadmium and nickel by Azolla species. Indian Journal of Plant Physiology 3: 302–304.
4. Arora A., Saxena S. 2005. Cultivation of Azolla microphylla biomass on secondary-treated Delhi municipal effluents. Biomass Bioenergy 29:60–64.
5. Arora A., Saxena T., Sharma D.K. 2006. Tolerance and phytoaccumulation of chromium by three Azolla species. World Journal of Microbiology & Biotechnology 22: 97–100.
6. Ashraf H., Matto FA., Ganai AM., Reshi IM., Sheikh FA. 2015. Effect of replacement of mustard oil cake with Azolla (Azolla pinnata) meal on growth performance of broilers and economics of feeding under temperate conditions. Indian J Anim Nutr 32:325–328.
7. Basak B., Pramanik MAH., Rahman MS., Tarafdar SU., Roy BC. 2002. Azolla (Azolla pinnata) as a feed ingredient in broiler ration. Int J Poult Sci 1:29–34.
8. Basset, N., Katsou, E., Frison, N., Malamis, S., Dosta, J. &Fatone, F. 2016 Integrating the selection of PHA storing biomass andnitrogen removal via nitrite in the main wastewater treatmentline. Bioresource Technology 200, 820–829.
9. Babu D.J., Sumalatha B., Venkateswarulu T.C., Das K.M., Kodali V.P. 2014. Kinetic, equilibrium and thermodynamic studies of biosorption of Chromium (VI)

ISSN 3030-3907

from aqueous solutions using Azolla Filiculoidus. Journal of Pure and Applied Microbiology, 8(4), 3107–3116.
10. Benaroya, B.O., V. Tzin, E. Tel-Or, and E. Zamski. 2004. Lead accumulation in the aquatic fern Azolla filiculoides. Plant Physiology and Biochemistry 42: 639–645.
11. Bennicelli R., Stezpniewska C.B., Banach A., Szajnocha K., Ostrowski J. 2004. The ability of Azolla caroliniana to remove heavy metals (Hg(II), Cr(III), Cr(VI)) from municipal waste water. Chemosphere 55: 141–146.
12. Bottomley W. B. 1920. The effect of organic matter on the growth of various water plants in culture solution. Ann. Bot. 34: 353-365.
13. Brouwer P., van der Werf A., Schluepmann H., Reichart G-J., Nierop KG. 2015. Lipid yield and composition of Azolla filiculoides and the implications for biodiesel production. Bioenergy Res. Pp. 1–9.
14. Cohen RR. 2006. Use of microbes for cost reduction of metal removal from metals and mining industry waste streams. J Clean Prod 14: 1146–1157.
15. Hamdi YA 1982. Applicationofnitrogen-fixingsystemsinsoilimprovement and management. Food Agric Org. Pp. 25-30.
16. Hardy D.W., Halstein R., Jakson E., Buens R.S. 1968. C_2H_2 - C_2H_4 asay to N_2 fixation laboratory and field evaluation. Plant Phys. V.43. Pp. 9-13.
17. Hardy R.W.F., Burns R.C., Herbert R.R., Holsten R.D., Jackson E.K. 1971. Biological nitrogen fixation: a key to world protein. // Plant and Soil/ Special vol. - Pp. 561-590.
18. Kangmin L. 1988. Rice-fish culture in China: a review. Aquaculture 71: 173–186.
19. Mosa, K. A., Saadoun, I., Kumar, K., Helmy, M. &Dhankher,O. P. 2016 Potential biotechnological strategies for thecleanup of heavy metals and metalloids. Frontiers in PlantScience 7, 303–303.
20. Morgan-Sagastume, F., Hjort, M., Cirne, D., Gérardin, F., Lacroix,S., Gaval, G., Karabegovic, L., Alexandersson, T., Johansson,P., Karlsson, A., Bengtsson, S., Arcos-Hernandez, M.,Magnusson, P. &Werker, A. 2015 Integrated production ofpolyhydroxyalkanoates (PHAs) with municipal wastewaterand sludge treatment at pilot scale. Bioresource Technology181, 78–89

ISSN 3030-3907