

BIOTECHNOLOGY FOR REMOVING CHROMIUM IONS FROM TEXTILE DYEING WASTEWATER USING MACROALGAE

Dadabayeva Ozodaxon Savriddin kizi

Trainee Researcher at the Institute of Microbiology, Academy of Sciences

Annotation: This article presents information on the biotechnological purification of wastewater generated by textile dyeing industries using higher aquatic plants — water hyacinth (*Eichhornia crassipes*) and duckweed (*Lemna minor* L.).

Keywords: wastewater, water hyacinth (*Eichhornia crassipes*), duckweed (*Lemna minor* L.), chromium(III) ion, chromium(VI) ion, biotechnological water treatment.

INTRODUCTION

In the textile dyeing process, chromium compounds (usually chromium salts such as potassium dichromate – $K_2Cr_2O_7$ or chromium(III) sulfate – $Cr_2(SO_4)_3$) are used as mordants (i.e., substances that fix the dye to the fiber).

Chromium may precipitate depending on reaction conditions:

If the pH is acidic, chromium(III) ions (Cr^{3+}) remain well dissolved in the solution. No precipitate forms, and the dye binds to the fiber through chromium. This is beneficial in dyeing since chromium acts as a “bridge” between the dye and the fiber.

If the pH is neutral or alkaline (e.g., when alkali is added), chromium(III) hydroxide ($Cr(OH)_3$) is formed:

To prevent chromium from precipitating during the dyeing process, the solution is kept acidic (pH \approx 3–4). If the environment becomes alkaline, chromium(III) hydroxide forms as a precipitate. Chromium(III) hydroxide — $Cr(OH)_3$ — is almost insoluble in water and does not dissociate into ions.

Plants generally absorb elemental nutrients in ionic form (e.g., Cr^{3+} , CrO_4^{2-}) through their roots. Since $Cr(OH)_3$ is insoluble, it cannot be directly taken up by roots. Only in certain situations — for example, under acidic conditions created by organic acids secreted from the roots or via microbial activity — $Cr(OH)_3$ may dissolve to form Cr^{3+} ions. These ions can then be absorbed by root cells.

Biotransformation and absorption mechanism.

Some aquatic plants and microorganisms can absorb chromium(III) in the form of biological complexes (e.g., bound to amino acids or proteins). Accumulation mainly occurs in the roots or plant parts directly in contact with water.

MATERIALS AND METHODS

Absorption of chromium-based blue compounds by aquatic plants

Chromium compounds that give a blue or bluish-green color are usually in the form of chromium(III), such as:

$Cr_2(SO_4)_3$ – chromium(III) sulfate (blue-green solution)

$[Cr(H_2O)_6]^{3+}$ – chromium(III) aquacomplex (bluish solution)

$Cr(OH)_3$ – chromium(III) hydroxide (green precipitate)

These contain Cr^{3+} ions and may be soluble or partially soluble in water.

In many cases, chromium accumulates in leaves or root tissues. The ability of aquatic plants to absorb chromium(III) (the “blue compound”) varies by species:

Plant species	Absorption characteristics
Eichhornia hyacinth)	(Water Accumulates Cr in both leaves and roots; very effective in purification.
Pistia (Water lettuce)	Accumulates Cr in roots and cell walls as Cr–complexes.
Lemna minor (Duckweed)	Mainly accumulates chromium in leaves.

Most effective chromium absorbers:

Water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*) because they can biologically transform Cr^{3+} into absorbable forms and reduce chromium pollution in water.

Physiological effects of chromium accumulation (especially Cr(VI) and high concentrations of Cr(III)) in water hyacinth:

Leaves become dry, yellowish, or damaged. Chromium ions strongly bind to leaf proteins, inhibiting enzyme activity. Photosynthesis slows down, reducing the plant’s ability to produce nutrients. Mitochondria and plasma membranes of leaf cells are damaged. Water retention capacity decreases, causing dehydration and leaf drying.

Oxidative stress increases: Cr(VI) induces free radicals (O_2^- , H_2O_2) in plant cells. Free radicals damage cell walls, leading to tissue destruction and leaf desiccation.

Signs of Chromium Toxicity in *Eichhornia crassipes* (Step-by-Step)

Stage	Symptoms	Cause
Stage 1	Yellowing of leaf edges	Chlorophyll degradation

Stage	Symptoms	Cause
Stage 2	Leaf stiffening, appearance of small spots	Protein denaturation
Stage 3	Leaf drying, darkening of the lower part	Disruption of water exchange
Stage 4	Complete wilting and leaf drop	Death of living cells

When chromium accumulates in the leaves of *Eichhornia crassipes*, especially Cr(VI) or excess Cr(III), it breaks down chlorophyll, reduces the leaf's water-retention capacity, and causes drying. Therefore, although water hyacinth is effective as a bioremediator in chromium-contaminated water, the plant itself gradually becomes damaged.

Biogeochemical cycling question:

Does the chromium accumulated in the plant return to the water after the plant dies?

As the leaves wilt and begin to decompose, their organic matter breaks down. During decomposition, chromium is released from organic complexes. A part of the released chromium dissolves in water, while another portion remains as sediment.

Chromium released into water (especially Cr(VI)) becomes toxic to other aquatic plants, fish, and microorganisms.

For this reason, water hyacinth used as a biofilter must be removed before it decays in the water. If decaying plant residues remain in the water, some of the accumulated chromium will return to the environment. Therefore, after purification, *Eichhornia* residues should be collected and removed — either dried and disposed of or incinerated — rather than being allowed to decompose in water.

RESEARCH RESULTS

A mixture was prepared:

5 L of chromium-containing textile dyeing wastewater + **250 L** of tap water;

20 plants of water hyacinth (*Eichhornia crassipes*) + **100 g** of duckweed (*Lemna minor* L.) were used.

Conditions:

Room temperature: **30–33°C**

Water temperature: **23–27°C**

pH: **5–7** (neutral to slightly acidic)

Microflora: normal

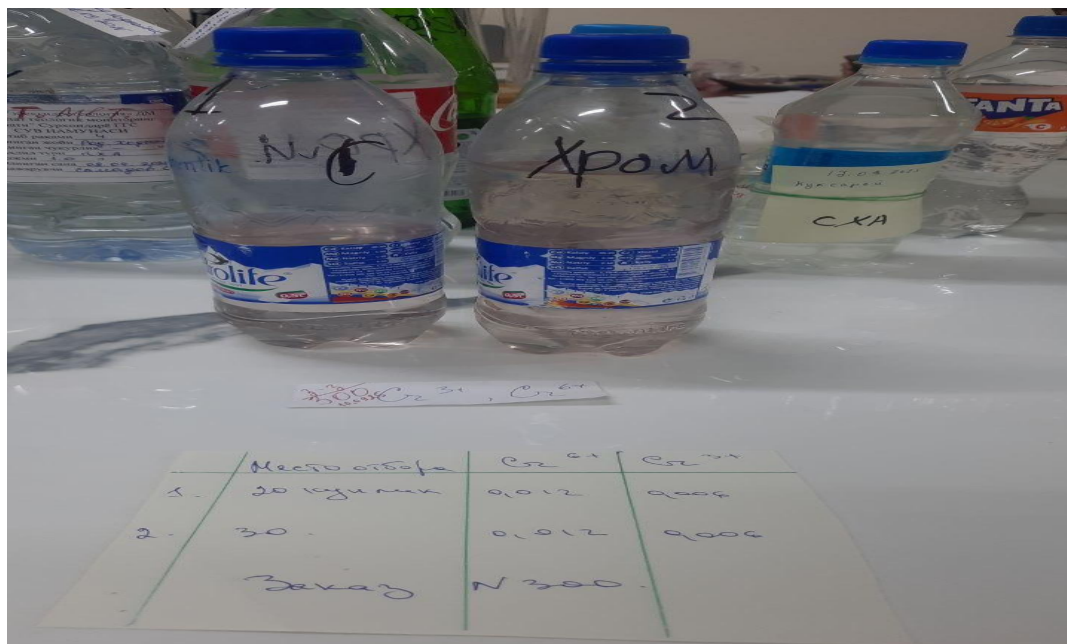
Plants: healthy

The initial chromium concentration was low: $Cd \approx 0.196 \text{ mg/L}$.

Below are the remaining concentrations of Cr(III) and Cr(VI) after 1, 5, 10, 15, 20, 25, and 30 days (mg/L):

Chromium Removal Efficiency (mg/L) by Macroalgae Combination (Lemna minor L. + Eichhornia crassipes) in Textile Dyeing Wastewater

N ^o	Variants	Chromium ion reduction over time (mg/L)	1 day	5 days	10 days	15 days	20 days	25 days	30 days
1	Cr(III)		0.196	0.1644	0.1010	0.0693	0.0377	0.006	0.006
	Cr(VI)		0.196	0.1347	0.1040	0.0734	0.042	0.012	0.012



Growth of Duckweed (Lemna minor L.) in Textile Dyeing Wastewater (g/m²)

N ^o	Conditions	Duckweed growth over days (g)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
1	5% dyeing wastewater + 95% tap water		100	150	285	500	725	800	890	920	1000	1100



CONCLUSION

Macroalgae such as water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes* L.), and duckweed (*Lemna minor* L.) can absorb both chromium(III) and chromium(VI) ions in ionic form as well as in biologically complexed forms (e.g., bound to amino acids or proteins) with the help of their roots and root-associated microorganisms.

Among these macroalgae, water hyacinth (*Eichhornia crassipes*) is considered the most effective species for the bioremediation of wastewater.

After treating chromium-contaminated water, water hyacinth residues should be removed either by drying or incineration, and must not be left to decompose in water. If dried leaves are not removed, a portion of the released chromium dissolves back into the water, while another portion remains as sediment. Chromium released into water (especially in the form of Cr(VI)) is toxic to other aquatic plants, fish, and microorganisms.

The study results indicate that macroalgae actively remove chromium ions and purify wastewater within **1–15 days**, whereas during **15–30 days**, their activity shifts to a passive removal process.

Literature:

1. Adey, W. H., & Loveland, K. *Dynamic Aquaria: Building and Restoring Living Ecosystems*. Academic Press, 2007.

2. Chan, S. M., Khoo, K. S., Chew, K. W., Ling, T. C., & Show, P. L. "Application of macroalgae for the removal of textile dyes from industrial wastewater." *Journal of Environmental Chemical Engineering*, 2020.
3. Kumar, P., & Pal, A. "Green macroalgae for bioremediation of dye-containing wastewater: A review." *Bioresource Technology*, 2019.
4. Rani, M. J., & Hemalatha, R. "Biodegradation of azo dyes using marine macroalgae." *Environmental Biology Reports*, 2018.
5. Wang, Y., & Chen, L. "Marine macroalgae as biofilters for dye-laden effluents." *Ecological Engineering*, 2017.
6. Singh, R., & Sharma, B. "Textile wastewater treatment using macroalgae-based constructed wetland systems." *International Journal of Environmental Science and Technology*, 2021.
7. Zepeda, V., & Quezada, M. "Phytoremediation of industrial dyes using freshwater macroalgae." *Water Science & Technology*, 2015.
8. Awasthi, A., & Tiwari, S. "Bioremediation potential of *Cladophora* species for dye removal." *Environmental Monitoring and Assessment*, 2016.
9. Deniz, F. "Biosorption of Basic Red 46 by green macroalga *Ulva lactuca*." *Separation Science and Technology*, 2020.
10. Schiewer, S., & Wong, M. H. *Algae and Aquatic Biomass for Wastewater Treatment and Resource Recovery*. Springer, 2016.
11. Xudoyberdiyev, A. N., & Yo'ldosheva, S. S. "Oqava suvlarni biotexnologik usulda tozalashda suv o'tlarining roli." *O'zbekiston Biologiya Jurnal*, 2019.
12. Matyokubov, M. M., & Nazarova, M. M. "Sanoat oqava suvlaridan bo'yoqlarni mikro va makrosuv o'tlari yordamida tozalash istiqbollari." *Universum: Kimyo va Biologiya*, 2020.
13. Ergashev, D. E., & Toshqulova, N. "Makrofitlar asosida bo'yoqli sanoat oqava suvlarini tozalashning ekologik samaradorligi." *Ekologiya va Atrof-muhit Jurnal*, 2021.
14. Raximov, A. T., & Qosimova, Z. "Tekstil oqava suvlaridagi azo bo'yoqlarni biologik parchalanishi." *Toshkent Kimyo-Texnologiya Instituti Ilmiy Axboroti*, 2020.
15. Jo'raqulov, B. O., & Sobirova, M. "Chuchuk suv makroalgalarning og'ir metallar va bo'yoqlarni biosorbsiyalash xususiyatlari." *O'zbekiston Ekologiya Jurnal*, 2018.
16. Mirzaahmedov, O. B., & Karimova, N. "Oqava suvlarni algalar yordamida tozalash biotexnologiyasi." *Biotexnologiya Asoslari*, Toshkent: Fan nashriyoti, 2017.
17. Tursunov, R. T., & Boboyeva, S. "Biologik tozalash tizimlarida makrofitlarning qo'llanilishi." *O'zbekiston Suv Resurslari Jurnal*, 2021.
18. Eshqobilova, M. M., & Alimova, S. A. "Ulva va *Cladophora* turlarining tekstil bo'yoqlariga nisbatan biosorbsion faolligi." *Biologiya va Tibbiyot Muammolari*, 2022.
19. Qayumova, D. R., & Xolmirzayev, B. "Sanoat oqava suvlarini fitoremediatsiya qilishning zamonaviy yondashuvlari." *Toshkent Davlat Universiteti Ilmiy Axboroti*, 2019.
20. Ortiqova, G., & Abdullayeva, N. "Makrosuv o'tlarining reaktiv bo'yoqlarni yutilish jarayonidagi biokimyoviy o'zgarishlar." *Bioekologiya va Biotexnologiya*, 2020.