

Lead Ion Removal from Water Using Fava Beans Pod-Derived Phytoadsorbents: A Green Approach

Salaheddin A. Sharif^{1,*}, Widad S. El-Mugrbi², Hamed A.M.N. El-Moghrabi²,
Mohamed A.B. Mostafa³, Adel Alsharkasi⁴, Khadija A. Abubakr⁵,
Reham B.A.-H. Al Hussein⁵

Abstract

The contamination of natural ecosystems, particularly water bodies, with harmful chemical substances poses a serious environmental threat on a global scale. Among these contaminants, toxic heavy metals such as lead, arsenic, cadmium, and mercury are especially concerning due to their non-biodegradable nature and ability to accumulate in living organisms. These metals can enter the human body through the food chain, even at trace levels, leading to various severe health issues, including neurological, developmental, and organ-related disorders. Therefore, the development of eco-friendly, cost-effective, and sustainable technologies for removing such contaminants from aquatic systems is of high importance. In this study, we explored the potential of a phytoadsorption-based approach for lead ion removal using an agricultural waste material, empty fava bean pods. Dried pods were ground to particles ranging in size from 350 to 1000 μm and used as bioadsorbents under ambient conditions and neutral pH. A series of batch adsorption experiments were conducted to evaluate the removal efficiency. The results showed a considerable removal rate of lead ions, reaching up to 58.2%. Furthermore, the adsorption capacity of the biomass was determined to be as high as 50.0 mg/g, especially when low amounts of dry biomass were applied. These findings suggest that fava bean pods are a promising, low-cost bioadsorbent for treating heavy metal-contaminated water.

Keywords: Lead ions, phytoadsorption, fava beans pods, bioadsorbent, heavy metal contamination

*Author for Correspondence

Salaheddin A. Sharif
E-mail: s.sharif@uob.edu.ly

¹Assistant Professor, Mercury Research Group, Department of Chemistry, Faculty of Arts and Science, University of Benghazi, Ghemines, Libya

²Assistant Professor, Department of Botany, Faculty of Arts and Science, University of Benghazi, Ghemines, Libya

³Assistant Professor, Department of Chemistry, Faculty of Science, Tobruk University, Tobruk, Libya

⁴Professor, Department of Statistics, Faculty of Science, University of Benghazi, Benghazi, Libya

⁵Student, Department of Biology, Faculty of Education, University of Benghazi, Ghemines, Libya

Received Date: April 05, 2025

Accepted Date: June 18, 2025

Published Date: June 21, 2025

Citation: Salaheddin A. Sharif, Widad S. El-Mugrbi, Hamed A.M.N. El-Moghrabi, Mohamed A.B. Mostafa, Adel Alsharkasi, Khadija A. Abubakr, Reham B.A.-H. Al Hussein. Lead Ion Removal from Water Using Fava Beans Pod-Derived Phytoadsorbents: A Green Approach. Journal of Water Pollution & Purification Research. 2025; 12(3): 53–58p.

INTRODUCTION

Contamination of aquatic systems by heavy metals is a global issue. The removal of these contaminants can be achieved using natural materials. Phytoremediation is a green and powerful technique that has been used in recent decades to remove pollutants from water using dead biomass of plants [1]. The phytoadsorption process has emerged as a potential process for the uptake of both essential heavy metals (iron, Fe; zinc, Zn; copper, Cu; cobalt, Co; manganese, Mn) and non-essential heavy metals (arsenic, As; lead, Pb; cadmium, Cd; chromium, Cr; mercury, Hg; and nickel, Ni) from aquatic systems [2–4]. Anthropogenic activities and natural sources are the main contributors to heavy metal pollution in environment [5, 6]. Toxicity of certain heavy metals is linked to their ability to accumulate in soft tissues of humans and animals leading to a wide range of disorders or diseases [7–11]. Removal of these toxic metals from aquatic

systems can be performed by phytoadsorption method using different types of plants and agricultural wastes [12–21]. Recently, we reported the efficiency of phytoadsorption in removing lead ions from aqueous solutions using dry fava beans (*Vicia faba* L.), dry empty fava beans pods, and dry pomegranate peels as potential bioadsorbents [22–25]. In this report, we investigated the phytoadsorption of lead ions from their aqueous solutions using dry empty fava bean pods for a prolonged time period.

MATERIAL AND METHODS

Sample Preparation

Lead Ions (Pb^{2+})

A 100 ppm solution of lead ions was prepared by dissolving lead nitrate, $Pb(NO_3)_2$, in distilled water. This concentration was used in all subsequent experiments.

Biomass of Empty Fava Beans Pods

Fresh fava beans were collected from the local market, Benghazi city, Libya. The fava beans pods were emptied from seeds, washed with water, and dried in dark place for 2 months. Next, they were ground and an amount of 350–1000 μm particles were sieved with two sieves. The dry particles were then stored in dark and dry place for next steps [24].

Phytoadsorption Experiments and Analysis of Samples

All experiment procedures and sample analyses were conducted according to standard methods [22–25]. Dry empty fava beans pods particles (2.0, 1.0, 0.50, or 0.10 g) were separately added to 100 ml of the lead nitrate solution (100 ppm) for each sample in a 500 ml polyethylene bottle. Each bottle was shaken using instrumental shaker (Flask Shaker SF1) at different rates (200, 400, 600, and 800 OSC/min) for 90 min at room temperature without altering the pH of the solution. Next, all bottles were left for 24 h to allow the biomass to precipitate. Afterward, the settled solutions were filtered using Whatman filter papers No. 1. The resulting filtrates were then diluted to 1 ppm and acidified with 0.5 ml of 60% nitric acid to maintain the pH at around 3, and stored in a refrigerator for the next steps. Then, the lead ion concentration in each filtrate was determined using a flame atomic absorption spectroscopic (FAAS) instrument (Model: Perkin Elmer 500) at room temperature of 24°C and a pH range of 2.5–3.6. Finally, the removal percentage (%) of lead ions and the adsorption capacity q_e (mg/g) were calculated. The adsorption capacity of each sample after equilibrium was determined by mass balance relationship equation as follows:

$$q_e = (C_i - C_d) V / W$$

Where C_i is the initial concentration of lead ion solution (mg/l), C_d is the detected concentration of filtrate solutions (mg/l), V is the volume of the solution (l) and W is the mass of adsorbate (g) [9, 20].

RESULTS AND DISCUSSION

Shaking Rate (200 OSC/min)

Shaking of different amounts of biomass (2.0, 1.0, 0.5, and 0.1 g) for 90 min were achieved. In general, a decrease in the fluctuation of the removal percentage of lead ions was observed in entries 1–4 (Table 1 and Figure 1).

Shaking Rate (400 OSC/min)

The removal percentage of lead ions from their aqueous solutions by fava bean pod particles (2.0, 1.0, 0.5, and 0.1 g) showed a similar pattern from 58 to 34.1% (entries 5–8, Table 1 and Figure 1) after 90 min of shaking. These results were slightly better than those from the previous four experiments.

Shaking Rate (600 OSC/min)

At the same period of time (90 min) using the same amounts of biomass particles (2.0, 1.0, 0.5, and 0.1 g), the removal percentage of lead ions from their solutions showed the same efficiency of the shaking rate of 400 except for the 9th experiment, which exhibited a higher percentage (entry 9, Table 1).

Table 1. The removal percentage of Pb^{2+} (%) and adsorption capacity, q_e , (mg/g) after shaking using dry empty fava beans pods.

Entry	Biomass (g)	Shaking rate (OSC/min)	Pb removal (%)	Adsorption capacity (mg/g)
1	2.0	200	58.0	2.90
2	1.0	200	27.3	2.73
3	0.5	200	47.9	9.58
4	0.1	200	20.7	20.7
5	2.0	400	58.0	2.90
6	1.0	400	42.4	4.24
7	0.5	400	49.7	9.94
8	0.1	400	34.1	34.1
9	2.0	600	58.2	2.91
10	1.0	600	42.0	4.20
11	0.5	600	42.4	8.48
12	0.1	600	31.5	31.5
13	2.0	800	55.8	2.79
14	1.0	800	29.8	2.98
15	0.5	800	26.9	5.38
16	0.1	800	50.0	50.0

Conditions: Pb^{2+} concentration = 100 ppm. Particle size of dry empty fava beans pods: 350–1000 μm . Contact time: 90 min. Bottle volume: 500 ml. Sample volume: 100 ml.

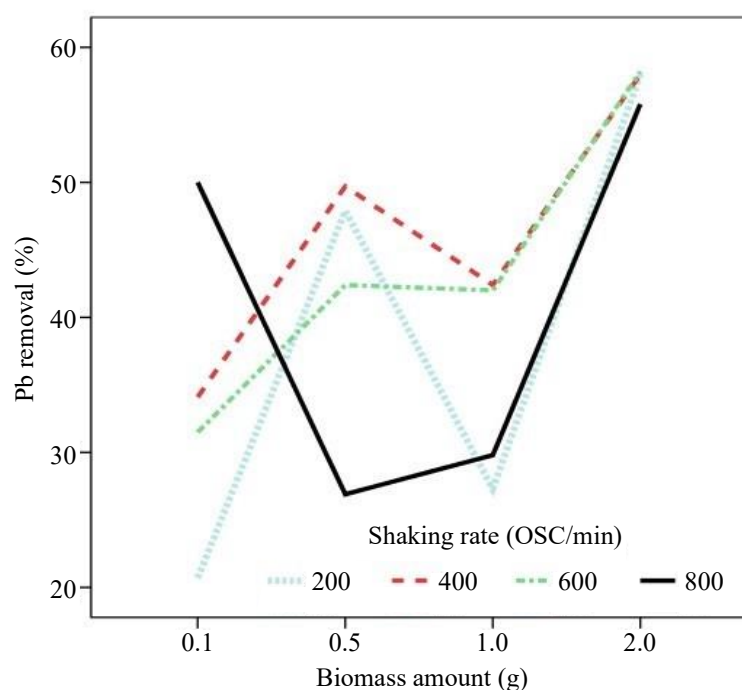


Figure 1. Removal percentage of Pb^{2+} after shaking using dry empty fava beans pods.

Shaking Rate (800 OSC/min)

The removal percentage of lead ions by fava bean particles was moderate, with the highest percentage reaching 55.8% (entries 13–15) after the same consumed time and the same biomass loading. Interestingly, the lowest loading of biomass (0.1 g) has showed a removal percentage of 50% which represents unusual result compared with the other experiments.

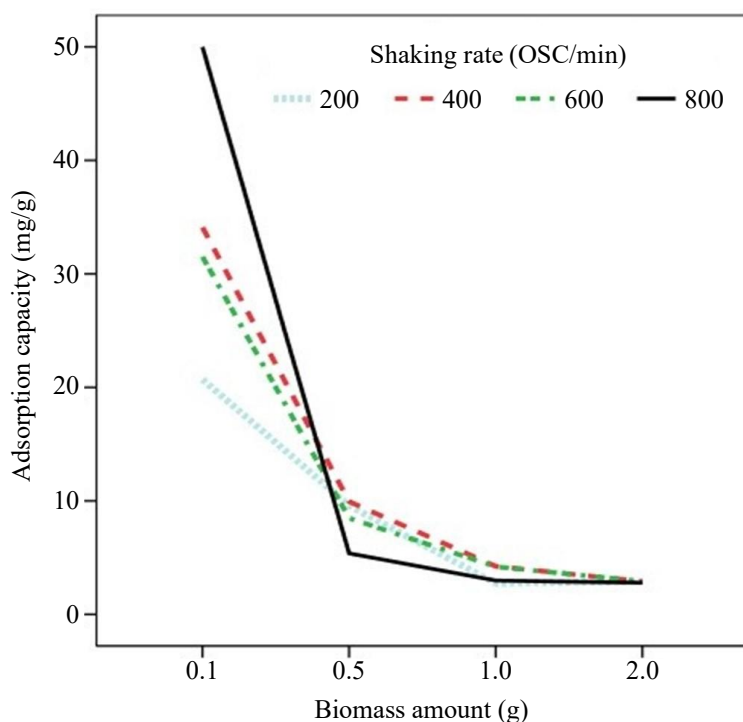


Figure 2. Adsorption capacity, q_e , of dry empty fava beans pods for removal of Pb^{2+} .

Based on the observed data, the efficiency of phytoadsorbent particles of dry empty fava beans pods (size of 350–1000 μm) for the removal of lead ions from their aqueous solutions in the designed experiments was good. Generally, the removal percentage of lead ions increased gradually by increasing the biomass loading with some exceptions. On the other hand, it was observed that conducting the designed experiments with a moderate shaking rate showed high removal of lead from the aqueous media. These results are consistent with the findings from our previous report [24].

ADSORPTION CAPACITY OF DRY EMPTY FAVA BEANS PODS

Generally, the adsorption capacity (q_e) of the dry particles of fava beans pods for removing lead ions from their aqueous solutions was moderate in most experiments under the conditions used (Table 1 and Figure 2). In all rates of shaking, it was observed that the adsorption capacity was gradually decreased due to the increasing amounts of the loaded biomass. This efficiency was in agreement with our previous work for taking up lead ions from their aqueous solution using the same biomaterial at the same shaking rates [24].

CONCLUSION

Phytoadsorption is an efficient approach for removing heavy metals from their solutions using biowaste materials. Consequently, the 350–1000 μm sized-particles of dry empty fava beans pods were able to uptake lead ions from their 100 ppm-aqueous solutions at different shaking rates during the same duration (90 min). In addition, the observed adsorption capacity increased as the biomass loading decreased.

Acknowledgement

The authors would like to thank to Dr Najwa H. Ansir, and Rehab N. Daggari (MSc), Department of Chemistry, Faculty of Science, for providing the Instrumental Shaker (Flask Shaker SF1). The authors would also like to thank Dr Hussein B. Jenjan, Department of Zoology, Abdusslam Elmogasapi, Department of Botany, Salh Ahmed Alsunousi, Department of Chemistry, Faculty of Science, and Khaled Ali Jhawi, Faculty of Arts and Science – Ghemines, for their help and providing all necessary facilities.

The authors are also thankful to Farag M. Ali, Quality Control Specialist, Water Quality Control Department, Man-Made River Project, Benghazi–Libya, for conducting the atomic absorption analysis.

Conflict of Interest

None.

Authors' Contributions

All authors contributed to data analysis, drafting, and revising the paper and agreed to be responsible for all aspects of this work.

REFERENCES

1. Redha AA. Removal of heavy metals from aqueous media by biosorption. *Arab J Basic Appl Sci.* 2020; 27(1): 183–193.
2. Bhat SA, Bashir O, Haq SA, Amin T, Rafiq A, Ali M, Américo-Pinheiro JH, Sher F. Phytoremediation of heavy metals in soil and water: An eco-friendly, sustainable and multidisciplinary approach. *Chemosphere.* 2022 Sep 1; 303(Pt 1): 134788.
3. Karman SB, Diah SZ, Gebeshuber IC. Raw materials synthesis from heavy metal industry effluents with bioremediation and phytomining: a biomimetic resource management approach. *Adv Mater Sci Eng.* 2015; 2015(1): 185071.
4. Rajakaruna N, Tompkins KM, Pavicevic PG. Phytoremediation: an affordable green technology for the clean-up of metal-contaminated sites in Sri Lanka. *Ceylon J Sci.* 2006; 35(1): 25–39.
5. Xiong T, Dumat C, Pierart A, Shahid M, Kang Y, Li N, Bertoni G, Laplanche C. Measurement of metal bioaccessibility in vegetables to improve human exposure assessments: field study of soil–plant–atmosphere transfers in urban areas, South China. *Environ Geochem Health.* 2016 Dec; 38: 1283–301.
6. Briggs D. Environmental pollution and the global burden of disease. *Br Med Bull.* 2003 Dec 1; 68(1): 1–24.
7. Mitra S, Chakraborty AJ, Tareq AM, Emran TB, Nainu F, Khusro A, Idris AM, Khandaker MU, Osman H, Alhumaydhi FA, Simal-Gandara J. Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity. *J King Saud Univ-Sci.* 2022 Apr 1; 34(3): 101865.
8. Zaynab M, Al-Yahyai R, Ameen A, Sharif Y, Ali L, Fatima M, Khan KA, Li S. Health and environmental effects of heavy metals. *J King Saud Univ-Sci.* 2022 Jan 1; 34(1): 101653.
9. Caito S, Aschner M. Neurotoxicity of metals. *Handb Clin Neurol.* 2015 Jan 1; 131: 169–89.
10. Pandey G, Madhuri S. Heavy Metals Causing Toxicity in Animals and Fishes. *Res J Animal Veterinary and Fishery Sci.* 2014; 2(2): 17–23.
11. Clarkson TW. Metal Toxicity in the Central Nervous System. *Environ Health Perspect.* 1987; 75: 59–64.
12. Huynh AT, Chen Y-C, Tran BNT. A Small-Scale Study on Removal of Heavy Metals from Contaminated Water Using Water Hyacinth. *Processes.* 2021; 9(10): 1802.
13. Etorki AM, El-Rais M, Mahabbis MT, et al. Removal of Some Heavy Metals from Wastewater by Using of Fava Beans. *Am J Anal Chem.* 2014; 5(4): 225–234.
14. Dubey A, Mishra A, Singhal S. Application of dried plant biomass as novel low-cost adsorbent for removal of cadmium from aqueous solution. *Int J Environ Sci Technol.* 2014; 11: 1043–1050.
15. Shartooh SM, Al-Azzawi MNA, Al-Hiyaly SAK. Pomegranate Peels as Biosorbent Material to Remove Heavy Metal Ions from Industrial Wastewater. *Iraqi J Sci.* 2013; 54(4): 823–831.
16. El-Ashtoukhya E-SZ, Amin NK, Abdelwahab O. Removal of lead (II) and copper (II) from aqueous solution using pomegranate peel as a new adsorbent. *Desalination.* 2008; 223(1–3): 162–173.
17. Sekhar KC, Kamala CT, Chary NS, et al. Removal of heavy metals using a plant biomass with reference to environmental control. *Int J Miner Process.* 2003; 68(1–4): 37–45.
18. Prasad MNV, Freitas H. Removal of toxic metals from solution by leaf, stem and root phytomass of *Quercus ilex* L. (holly oak). *Environ Pollut.* 2000; 110(2): 277–283.

19. Mallampati R, Xuanjun L, Adin A, et al. Fruit Peels as Efficient Renewable Adsorbents for Removal of Dissolved Heavy Metals and Dyes from Water. *ACS Sustain Chem Eng*. 2015; 3(6): 1117–1124.
20. Ben-Ali S, Jaouali I, Souissi-Najar S, et al. Characterization and adsorption capacity of raw pomegranate peel biosorbent for copper removal. *J Clean Prod*. 2017; 142(Pt 4): 3809–3821.
21. Dube D, Chingoma C. Removal of Heavy Metal Ions from Household Drinking Water Using *Acacia Galpinii* Seeds and Seed Pods. *J Health Pollut*. 2016; 6(12): 7–14.
22. Sharif SA, El-Moghrabi HAMN, El-Mugrbi WS, et al. Fava Beans (*Vicia faba* L.) Phytosorption of Pb^{2+} Ions from its Aqueous Solutions. *Asian J Green Chem*. 2023; 7(2): 85–90.
23. Sharif SA, El-Mugrbi WS, El-Moghrabi HAMN, et al. Removal of Toxic Lead Ions from their Aqueous Solutions Using Fava Beans Phytoadsorption Technique. *AlQalam Journal of Medical and Applied Sciences*. Special Issue for 6th International Conference in Basic Sciences and Their Applications (6th ICBSTA, 2023). 2023; 71–86.
24. Sharif SA, El-Mugrbi WS, El Moghrabi HAMN, et al. Evaluation of Empty Fava Beans Pods as Bioadsorbent for the Removal of Pb^{2+} from Aqueous Solutions Using Phytoadsorption Technique. *Al-Mukhtar Journal of Basic Sciences (MJBS)*. 2024; 22(2): 114–122.
25. Sharif SA, Ansir NH, Eldagharye RNFM, et al. Evaluation of Pomegranate Peel as Bioadsorbent for Removing Lead Ions from Aqueous Solutions Using Phytoadsorption Technique. *Scientific journal for the Faculty of Science-Sirte University (SJFSSU)*. 2024; 4(2): 53–61.