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Edited by:
Prof. Abdussalam Salhin Mohamed.
Prof. Hisain Masoud Abomadina.
Dr. Ashraf Mustafa Abusenaina.
Dr. Fathia Abdulljawad Mosa

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Effect of Extending Contact Time on Efficiency of Fava Beans Pods as Bioadsorbents to Remove Lead Ions from Aquatic Solutions

***Salaheddin A. Sharif* [1*], *Widad S. El-Mugrbi* [2,3], *Hameda A. M. N. El-Moghrabi* [2,3], *Mohamed A. B. Mostafa* [4], *Adel Alsharkasi* [5], *Khadija A. Abubakr* [3], and *Reham B. A.-H. Al Hussein* [3]**

[1] *Mercury Research Group, Department of Chemistry, Faculty of Arts and Science, University of Benghazi, Ghemines, Libya*
[2] *Department of Botany, Faculty of Arts and Science, University of Benghazi, Ghemines, Libya*
[3] *Department of Biology, Faculty of Education, University of Benghazi, Ghemines, Libya*
[4] *Department of Chemistry, Faculty of Science, Tobruk University, Tobruk, Libya*
[5] *Department of Statistics, Faculty of Science, University of Benghazi, Benghazi, Libya*
Corresponding Author Email: s.sharif@uob.edu.ly

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***Abstract*:** Pollution of aquatic systems with toxic heavy metals is concernedly increased worldwide. Danger of these metals lies in their ability to bioaccumulate in human and living organisms through food chains. They can cause a wide range of diseases and disorders. Removal of heavy metals from contaminated media and cleaning the ecosystems require introducing effective and eco-friendly approaches which represents a challenge in itself. Phytoadsorption process, which is one of the bioremediation techniques, is a green, simple, inexpensive, and sustainable approach used for cleaning the aquatic systems from heavy metals. However, aim of this work is to utilize various loads of dry, empty fava beans pods particles (size: 350–1000 µm) as a bioadsorbent to remove Pb^{2+} from aqueous media at room temperature without making any change on pH of media. In all experiments, this biomaterial was able to remove up to 59.6% of lead ions with an adsorption capacity up to 59.6 mg/g after 120 minutes of shaking. Moreover, the phytoadsorbent showed significant efficiency compared to previous studies that used contact shaking times of 30, 60, and 90 minutes.

Introduction

Natural resources and anthropogenic activities are the major sources of the environmental pollution, in particular the aquatic systems, with toxic heavy metals (Xiong et al., 2016; Briggs, 2003). Toxicity of heavy metals is due to their bioaccumulation in soft tissues during metabolic processes. This bioaccumulation can cause various disorders and diseases (Mitra et al., 2022; Zaynab et al., 2022; Caito & Aschner, 2015; Pandey & Madhuri, 2014; Clarkson, 1987). Heavy metal removal from aquatic media can be effectively performed by phytoadsorption approach via utilizing a wide spectrum of dry biomass of plants (Dubey et al., 2014; Sekhar et al., 2003) and agricultural wastes (Mallampati et al., 2015) such as water hyacinth (Huynh et al., 2021), fava beans (Etorki et al., 2014), pomegranate peels (Shartooh et al., 2013; El-Ashtoukhya et al., 2008; Ben-Ali et al., 2017; Sharif et al., 2024; Ansir et al., 2025), *Quercus ilex* L. (holly oak) (Prasad & Freitas, 2000), and *Acacia Galpinii* seeds and seed pods (Dube & Chingoma, 2016). Phytoadsorption (Redha, 2020), which is one of the phytoremediating techniques, has emerged as a green and potential method used for removing heavy metals (Fe, Zn, Cu, Co, Mn, As, Pb, Cd, Cr, Hg, and Ni) from contaminated aquatic systems (Bhat et al., 2022; Karman et al., 2015; Rajakaruna et al., 2006). Recently, we reported the efficiency of fava beans (*Vicia faba* L.) in form of dry particles (Sharif et al., 2023), and empty fava beans pods (Sharif et al., 2024 & 2025) as potential bioadsorbents to remove lead ions from their aqueous solutions using phytoadsorption methodology at period of times (30, 60, and 90 min). In this work, we investigated the role of an extended time (120 minutes) on the ability of dry particles of empty fava bean for removing the ions of metal lead under similar conditions

Material and Methods

Preparation of Samples

Pb^{2+} Solution

A solution of lead ions with a concentration of 100 ppm was prepared using lead nitrate ($Pb(NO_3)_2$) and employed in all experimental procedures.

Dry Biological Mass of Empty Fava Beans Pods

The fava beans pods were obtained fresh from a local market (Benghazi, Libya). Then they were separated from seeds, dried, and ground. The required particles were prepared according to previous procedures (Sharif et al., 2024). Sieved particles ranging in size from 350 to 1000 μm were utilized in all experimental analyses.

Experiment and Analysis

All phytoadsorption experiments; procedures, conditions and sample analysis, were conducted as reported by Sharif group in 2023, 2024, and 2025 except for the contact time which was set to 120 minutes. The removal percentage (%) of lead ions from their aqueous solutions and the adsorption capacity q_e (mg/g) after equilibrium for each sample were all calculated (El-Ashtoukhya et al., 2008; Ben-Ali et al., 2017).

Results and discussion

Removal Percentage (%) of Pb^{2+} by Fava-Beans-Pods Biomass

200 OSC/min-Shaking Rate

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Lead ions-removal efficiency from aquatic media decreased from 58% to 21.5% as the amount of dry fava bean pod particles was reduced from 2.0, 1.0, 0.5 to 0.1 g (entries 1–4), after 120 minutes of shaking at room temperature (Table 1 and Figure 1). Notably, an exceptional result was observed when using 1.0 g of the biomass (entry 2).

400 OSC/min-Shaking Rate

At this rate, the pattern of lead ion removal was similar to that observed at a lower shaking speed of 200 OSC/min (entries 5–8). Overall, a slight increase in removal efficiency was noted with the increase in shaking speed from 200 to 400 OSC/min under identical conditions.

600 OSC/min-Shaking Rate

Increasing the shaking rate to 600 OSC/min did not result in a significant improvement in the lead ion removal percentage compared to the rate observed at 400 OSC/min (entries 10–12). In fact, a noticeable decrease of approximately 10% was observed, with removal percentage dropping from 58% at 400 OSC/min to 47.5% at 600 OSC/min when using the same amount of biomass (entry 9)

800 OSC/min-Shaking Rate

At the highest shaking speed, the dry fava bean pod particles were able to remove between 32.2% and 59.6% of lead ions, depending on the loaded biomass used (entries 13–16). While 2.0 g of dry particles achieved a removal efficiency of 53.3% (entry 13), the use of 0.1 g of biomaterial showed the highest removal percentage of 59.6% under the same conditions (entry 16).

The dry particles of empty fava bean pods, sized between 350 and 1000 μm, used in all experiments, demonstrated moderate efficiency in removing Pb^{2+} from aqueous solutions under standard conditions, including biomass amount, shaking rate, contact time, room temperature, and neutral *p*H (Sharif et al., 2024). Additionally, it was noted that the biomass loading could be reduced from 2.0 g to 0.1 g without significantly affecting the removal efficiency. Moreover, an enhanced removal of lead ions from the aqueous solutions could be achieved by increasing the shaking rate under the same conditions.

Furthermore, when compared to our previously reported studies (Sharif et al., 2024 & 2025), the observed results were generally consistent with those findings. Finally, as aimed for this research, increasing the contact time for all samples from 30 to 120 minutes can improve the lead ion removal percentage. This increase was particularly evident for most samples, in particular when using a lower biomass loading of the fava bean pod phytoadsorbent (0.1 g).

Table 1. Pb^{2+} removal percentage (%) and adsorption capacity, q_e, (mg/g).

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	28.6	2.86
3	0.5	200	43.1	8.62

4	0.1	200	21.5	21.5
5	2.0	400	57.8	2.89
6	1.0	400	42.8	4.28
7	0.5	400	49.4	9.88
8	0.1	400	35.8	35.8
9	2.0	600	47.5	2.38
10	1.0	600	42.9	4.29
11	0.5	600	48.3	9.66
12	0.1	600	33.6	33.6
13	2.0	800	53.3	2.67
14	1.0	800	32.2	3.22
15	0.5	800	35.9	7.18
16	0.1	800	59.6	59.6

Conditions: [Pb^{2+}] = 100 ppm. Fava beans pods-particle size: 350–1000 µm. Volume of bottle: 500 mL. Volume of sample solution: 100 mL. Experiment time: 120 min.

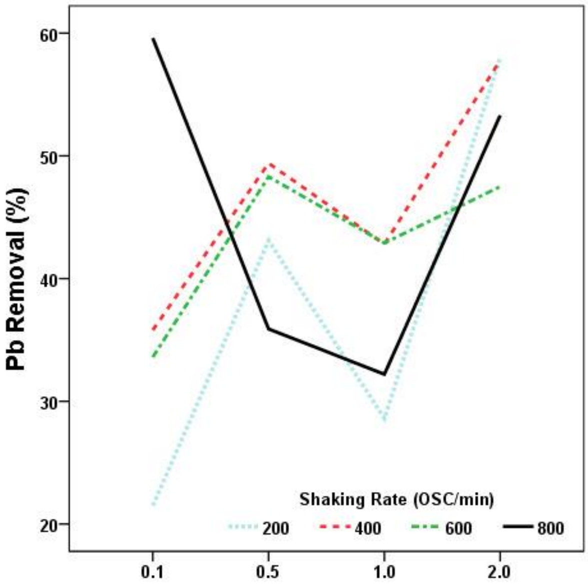

Figure 1. Lead ions-removal percentage (%) using dry particles of empty fava beans pods.

dsorption Capacity (q_e) of Dry, Empty Fava Beans Pods- Particles

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The biomass particles of fava beans-pods, sized between 350 and 1000 µm that used to remove Pb^{2+} from their solutions, showed an adsorption capacity ranged from low to moderate, depending on the amount of bioadsorbent used under the mentioned conditions (Table 1, Figure 2). In general, it was observed that the adsorption capacity increased due to the biomass amount decreased. The highest adsorption capacity was achieved with 0.1 g of bioadsorbent. Additionally, the adsorption capacity was found to improve with an increase in the shaking rate.

On the other hand, contact time proved to be a critical factor in the designed experiments, especially when compared to our previously reported data (Sharif et al., 2024 & 2025). The phytoadsorption capacity of fava beans pods in each sample generally increased due to extending of the contact time from 30 to 120 minutes, with a few exceptions.

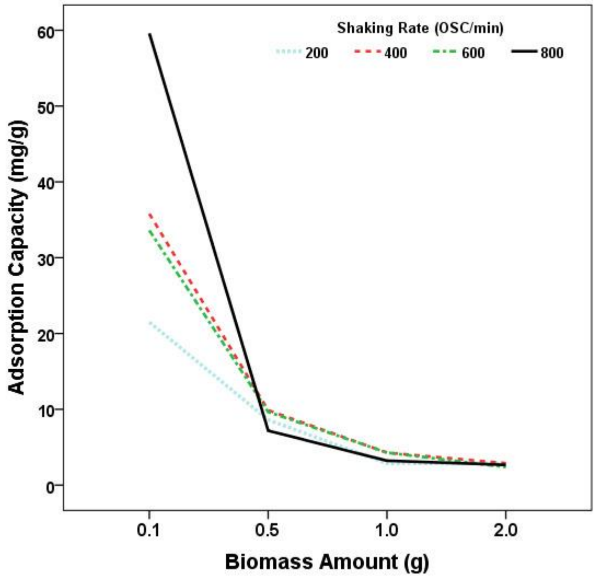

Figure 2. Adsorption capacity (q_e) of dry, empty-fava beans-pods particles to remove lead ions from aquatic solutions.

Conclusion

Phytoadsorption of lead ions from aqueous solutions (100 ppm) was achieved with moderate efficiency after 120 minutes of shaking using dry, empty fava bean-pods particles, sized between 350 and 1000 µm, at varying shaking rates (200, 400, 600, and 800 OSC/min). The removal percentage of Pb^{2+} gradually increased due to the increased amount of the biomass, with a few exceptions, particularly at the shaking rate of 800 OSC/min. Moreover, the dry particles of empty fava bean pods as bioadsorbents exhibited a range of adsorption capacities, from low to high, depending on both the biomass loading of pods and the shaking contact time. The highest observed adsorption capacity was achieved with the use of 0.1 g of the dry biomaterial particles across all shaking rates. In addition, it was observed that both the removal percentage and adsorption capacity in all experiments increased due to

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increasing the contact time from 30, 60, and 90 minutes, as reported in our previous studies (Sharif et al., 2024 & 2025), to 120 minutes in this study, under the same conditions.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

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

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