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Exploitation of *Ganoderma lucidum* as a biosorbent for lead-contaminated water: FTIR characterization and adsorption modeling

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Abstract

Heavy metal contamination in water is a critical environmental issue, with lead posing a substantial threat to human health and ecosystems. Conventional remediation techniques are often inefficient and expensive, necessitating the development of alternative strategies. This study explored the potential of the macrofungus *Ganoderma lucidum* for the biosorption of lead (Pb) ions from aqueous solutions. The biosorption process was analyzed using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) for Pb (II) quantification and Fourier-transform infrared spectroscopy (FTIR) to identify the functional groups involved. The results demonstrated a high adsorption capacity of *G. lucidum*, achieving 91.64% removal efficiency at a lead concentration of 600 ppm, pH 4, a biomass dosage of 5 g, and a 24-hour contact time. Additionally, Langmuir isotherm modeling was applied to better understand the biosorption mechanisms. These findings highlight the potential *of G. lucidum* as an eco-friendly and sustainable solution for lead removal in water treatment.

Keywords: Heavy metal contamination; Biosorption; *Ganoderma lucidum*; Lead removal; ICP-AES; FTIR; Langmuir isotherm; Water treatment; Environmental conservation

1. Introduction

Lead (Pb) is a highly toxic metal that has become a significant environmental contaminant owing to its widespread use, posing serious health risks to both ecosystems and humans [1,2]. In its pure form, Pb (II) is a bright, silvery metal exhibiting a characteristic bluish tinge. However, when exposed to air, it readily tarnishes due to chemical reactions with atmospheric components. This surface tarnishing results in the formation of various lead compounds, such as lead oxides, carbonates, and sulfides. Major sources of Pb (II) contamination include industrial processes, plumbing systems, gasoline, storage batteries, toys, and other household products [3]. A significant portion of Pb (II)is released into the environment through vehicle exhaust, where it becomes absorbed by plants, soil, and water, contributing to human exposure through the consumption of contaminated food and water [4].

The impact of Pb (II) on plant life is particularly concerning because it disrupts essential physiological functions. Unlike other metals, such as copper, zinc, and manganese, Pb (II) has no biological role in plant metabolism and induces the production of reactive oxygen species (ROS), which damage cell membranes and inhibit photosynthesis [5]. Lead toxicity manifests as oxidative stress and ionic mechanisms. Oxidative stress occurs when there is an imbalance between ROS production and antioxidant defense, leading to cellular damage. While antioxidants such as glutathione typically mitigate ROS activity, lead exposure elevates ROS levels and compromises these protective mechanisms [6,7]. Additionally, Pb (II) can replace essential bivalent cations, such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and iron (Fe^{2}), disrupting critical biological processes, including cell signaling, protein folding, and enzyme regulation [6]. This ionic disruption is particularly alarming in neurological processes, where Pb (II) can substitute for Ca and impact vital proteins, such as protein kinase C, which is crucial for neural function and memory storage.

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Given these harmful effects, traditional methods for removing lead and other heavy metals from contaminated environments, such as precipitation and ionic exchange, are often inadequate, particularly at low concentrations. This limitation has prompted the search for more sustainable remediation methods. Biosorption, which involves the use of biological materials to adsorb and remove heavy metals, presents a promising solution. This cost-effective and environmentally friendly method utilizes microorganisms, fungi, and plants to efficiently capture and remove heavy metals from contaminated water [8].

In this study, we focused on employing the biosorption technique, specifically utilizing the macrofungus *Ganoderma lucidum*, to efficiently remove lead ions from water-based solutions. Fourier-transform infrared spectroscopy (FTIR) will be employed to identify and analyze the various functional groups present in the fungal biomass responsible for the binding and removal of lead ions. Furthermore, by integrating data from inductively coupled plasma atomic emission spectroscopy (ICP-AES) and FTIR analyses, this study aims to provide valuable insights into the potential of *G. lucidum* as an effective bioagent for lead ion removal from water-based solutions. The findings of this study have significant implications for environmental remediation strategies and the development of sustainable methods for controlling heavy metal pollution.

2. Materials and Methods

All chemicals used in this study were of analytical grade and purchased from Sigma–Aldrich Chemical Co. (USA).

2.1. Metal Ion Solution Preparation

A standard stock solution of lead with a concentration of 1000 ppm was prepared by dissolving 1.60 g of lead in 1000 mL of deionized water. Different concentrations of this stock metal solution were prepared from 200 ppm to 1000 ppm by diluting the stock lead solution with deionized water.

2.2. Fungi used and adsorbent preparation

In this study, the macrofungus *G. lucidum* was collected from the Oval Garden in Mumbai, India. The collected fungi were thoroughly washed with tap water and then with deionized water to eliminate impurities. Subsequently, the washed fungi were completely dried under sunlight for seven days and finely powdered for further use.

2.3. Characterization

To identify the functional groups, present in the adsorbents within the 4000–400 cm-1 range, FTIR analysis was performed with metal-free and metal-loaded biomass. Before and after treatment, the metal ion solutions were analyzed using ICP-AES to monitor their concentrations.

2.4. Batch Adsorption Studies

During the batch adsorption equilibrium experiments, the effectiveness of *G. lucidum* as an adsorbent for removing Pb (II) from the solution was assessed using Eq. 1. To conduct the experiments, 25 g of the adsorbent was added to 1000 mL of lead solution with varying concentrations, and the mixture was placed in 250 mL conical flasks. The flasks were continuously shaken at a constant speed of 120 rpm and maintained at room temperature. The concentration of Pb (II) ions in the solution was measured using ICP-AES before and after the adsorption. Based on the measurements, the amount of adsorption at equilibrium (qe) (mg/g) and the percentage adsorption (%) were calculated using Eq. 2.

$$qe = \frac{(Co-Ce)\,V}{X} \quad \text{.....(Eq.1)}$$

$$\%\ of\ adsorption\ = \frac{(Co-Ce)}{Co}\ X\ 100 \quad \text{.....(Eq.2)}$$

In the context of adsorption, Co and Ce represent the initial and equilibrium concentrations of the pollutant in the solution (measured in mg/L), respectively. where V is the volume of the solution and X is the weight of the adsorbent used in the process (measured in grams) [9].

2.4.1. Effect of initial pH

Batch biosorption experiments were performed at varying pH values. The effect of initial pH on metal uptake was studied in the pH range of 2.0 to 10.0. This was done by adjusting the pH of the Pb (II) solution using 0.1M HCl and 0.1M NaOH.

2.4.2. Effect of contact time

The contact time influences the treatment efficiency of the biosorption process. The effect of contact time on the uptake of heavy metal ions was investigated in the range of 30–4320 min.

2.4.3. Effect of temperature

To study the effect of temperature on biosorption, the temperature of the aqueous solutions was adjusted in the range of 25–45°C.

2.4.4. Effect of adsorbent dose

Batch biosorption experiments were conducted using varying amounts of adsorbent. The adsorbent (1.0, 2.0, 3.0, 4.0, and 5.0 g) was added to 1000 mL of 100 mg/L Pb (II).

The experiments were performed under continuous shaking at 120 rpm.

3. Results and Discussion

3.1. Biosorption experiment

This study aimed to determine the optimal ppm concentration of *G. lucidum* oven-dried powder to maximize lead adsorption. The best adsorption occurred at a 600-ppm concentration according to this initial investigation. In subsequent experiments, this concentration of 600 ppm was used to investigate the effects of pH, time, dose, and temperature on biomass adsorption capacity. The biosorption efficiency of *G. lucidum* biomass at different initial Pb (II) concentrations is summarized in Table 1, while the corresponding trend is illustrated in Fig. 1.

Table 1 Biosorption efficiency of *G. lucidum* at different Pb (II) concentrations

SN	Before Treatment	After Treatment	% Biosorption
1	200 ppm	100.1	49.95
2	400 ppm	92.51	76.87
3	600 ppm	74.09	87.65
4	800 ppm	242.22	69.72
5	1000 ppm	494.13	50.58

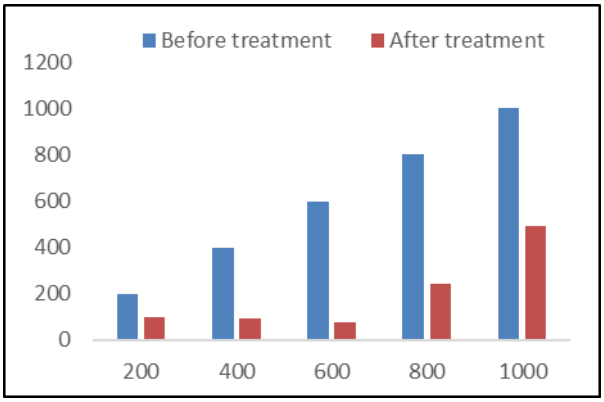

Figure 1 Graph showing the reduction of Pb (II)

3.2. Effect of contact time

The influence of contact time on lead biosorption by *G. lucidum* was evaluated over 30 min, 1 h, 3 h, 24 h, 48 h, and 72 h. The results showed that increasing the amount of biomass enhanced metal removal from the solution, as a larger biomass quantity provided more biosorption sites. The use of 5 g of fungal biomass with a 24-hour contact time resulted in the highest removal efficiency, reaching 91.65%. Beyond 24 h, a decline in biosorption efficiency was observed. These findings are consistent with the observations of [10]. The influence of contact time on Pb (II) biosorption by *G. lucidum* biomass is presented in Table 2 and Fig. 2.

Table 2 Effect of contact time on Pb (II) biosorption efficiency by *G. lucidum*

SN	Time	Reduction	% Biosorption
1	30 Min	385.10	35.81
2	1 hr	230.61	61.56
3	3 hr	190.81	68.19
4	24 hr	50.09	91.65
5	48 hr	309.12	48.48
6	72 hr	31.33	31.33

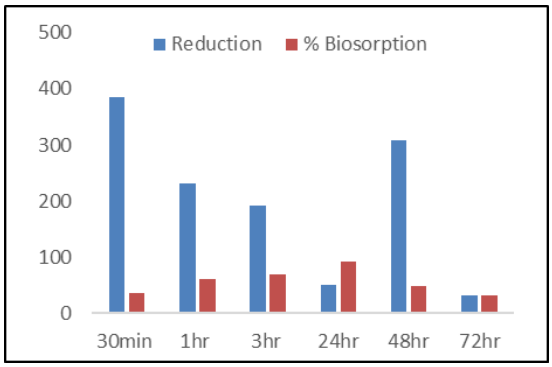

Figure 2 Effect of contact time on Pb (II) biosorption by G. lucidum

3.3. Effect of pH

pH is a critical factor in the biosorption of heavy metal ions by *Ganoderma*. The optimal pH was determined as 4 for Pb (II) uptake after 24 h. The variation in Pb (II) biosorption efficiency as a function of solution pH is shown in Table 3 and Fig. 3. These results are consistent with earlier findings for *Aspergillus versicolor* [11] and *Rhizopus oligosporus* [12]. At low pH levels, the biomass active sites are protonated, reducing the number of negatively charged binding sites available for metal coordination**.** At higher pH values, these sites are deprotonated and thus more accessible for metal binding. It is important to note that the impact of solution pH on biosorption may vary depending on the biomass type and the specific metal ion involved.

Table 3 Influence of pH on Pb (II) biosorption by *G. lucidum.*

SN	pH	Reduction	% Biosorption
1	2	21.83	21.83
2	4	50.94	91.65
3	6	127.01	78.83
4	8	360.19	39.96
5	10	490.01	18.33

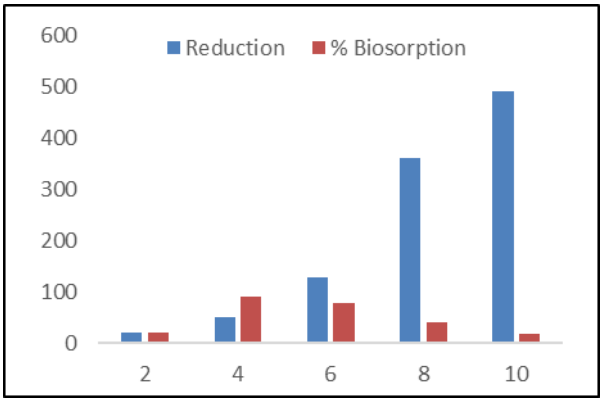

Figure 3 Effect of initial solution pH on Pb (II) biosorption efficiency by G. lucidum

3.4. Effect of Dosage

This study examined the effect of dosage on metal removal within the optimal range of 1–5 g. The results showed that increasing the biomass quantity enhanced metal uptake from the solution. In particular, applying 5 g of fungal biomass with a 24-hour contact time yielded the highest removal efficiency, likely because of the greater number of available biosorption sites. The quantity of biosorbent added directly determines the availability of binding sites for metal uptake. These observations are consistent with the findings of [10]. The effect of *G. lucidum* biomass dosage on Pb (II) removal efficiency is summarized in Table 4 and depicted in Fig. 4.

Table 4 Effect of *G. lucidum* biomass dosage on Pb (II) removal efficiency**.**

SN	Dosage	Reduction	% Biosorption
1	1	308.14	48.64
2	2	294.12	50.98
3	3	290	51.66
4	4	101.59	83.06
5	5	50.94	91.65

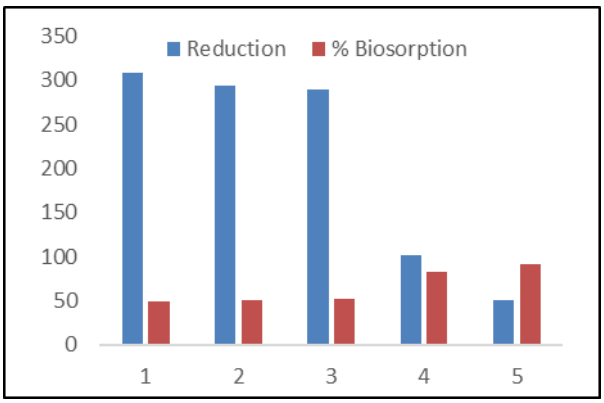

Figure 4 Effect of *G. lucidum* biomass dosage on Pb (II) removal efficiency

3.5. Effect of temperature

The effect of temperature on adsorption was evaluated across a range of 30–40°C, with specific assessments conducted at 25, 30, 35, 40, and 45°C. The highest adsorption capacity of 91.65% was recorded at 30 ± 1°C. In contrast, increasing the temperature beyond 35 ± 1°C led to a noticeable decline in the adsorption efficiency of the dried *Ganoderma* biomass, which dropped to 68.30% at 35°C. The influence of temperature on Pb (II) biosorption efficiency by *G. lucidum*

biomass is presented in Table 5 and Fig. 5. This trend demonstrates the temperature-sensitive nature of the adsorption process, where optimal performance occurs at lower temperatures, while higher temperatures—particularly above 40°C—result in reduced adsorption capacity (reaching as low as 26.48% at 45°C). These results are consistent with those of earlier studies involving *A. versicolor*, *R. oligosporus*, and *Bacillus subtilis* [11–13].

Table 5 Effect of temperature on Pb (II) biosorption efficiency by *G. lucidum*

SN	Temp	Reduction	% Biosorption
1	25	301.16	49.80
2	30	50.94	91.65
3	35	190.16	68.30
4	40	319.19	46.80
5	45	441.091	26.48

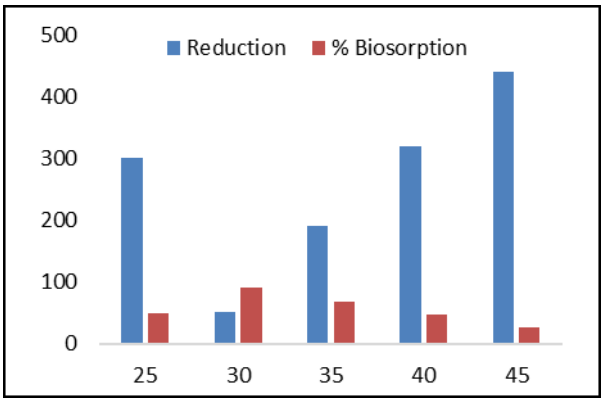

Figure 5 Effect of temperature on Pb biosorption by *G. lucidum*

3.6. Evidence of Pb (II) adsorption *in G. lucidum* through FTIR analysis

The FTIR spectra of *G. lucidum* biomass before and after Pb (II) adsorption are shown in Fig. 6. FTIR analysis of *G. lucidum* before and after exposure to Pb (II) demonstrated notable spectral modifications that confirmed the involvement of fungal functional groups in metal binding. Prior to treatment, the major absorption bands were recorded at 1974.4, 1628.7, 1026.2, 557, 702–707, and 457.3 cm^{-1}. These peaks correspond to overtones or combination bands, carbonyl/amide vibrations, C–O stretching of polysaccharides, and low-frequency skeletal vibrations that are typical of fungal cell wall components.

Following Pb (II) adsorption, new peaks emerged at 3736.9 cm^{-1}, 3424.5 cm^{-1}, 1037.4 cm^{-1}, 602.4 cm^{-1}, 502.0 cm^{-1}, and 435.0 cm^{-1}. The appearance of broad O–H/N–H stretching bands at 3736.9 cm^{-1} and 3424.5 cm^{-1} suggests that hydroxyl and amine groups play a significant role in Pb (II) binding, likely through hydrogen bonding or coordination interactions. Additionally, the shift from 1026.2 cm^{-1} to 1037.4 cm^{-1} indicates alterations in the C–O and C–O–C stretching vibrations, reflecting their participation in metal complexation. The formation of new bands in the 602–435 cm^{-1} region is characteristic of metal–oxygen (Pb–O) bonds, confirming the establishment of coordination interactions between Pb (II) ions and oxygenated functional groups within the fungal biomass.

These spectral changes collectively demonstrate that Pb (II) adsorption induces chemical modifications in the fungal cell wall and involves interactions with hydroxyl, carbonyl, amine, and polysaccharide-linked oxygen groups.

3.7. Disappearance of Peaks

The FTIR spectrum of the Pb (II)-treated biomass also revealed the complete disappearance of several characteristic absorption bands present in the untreated sample. Specifically, the peaks at 1974.4, 1628.7, 1026.2, 557, 702–707, and

457.3 cm^{-1} were no longer detected after Pb (II) exposure. The loss of these signals provides direct evidence of the involvement of the corresponding functional groups in Pb (II) binding.

The disappearance of the 1628.7 cm^{-1} band (amide/carbonyl region) suggests strong interactions between Pb (II) ions and C=O groups, resulting in complexation that alters the vibrational behavior of the bond. Similarly, the elimination of the 1026.2 cm^{-1} polysaccharide-associated band indicates that the C–O groups participated actively in Pb (II) coordination. The absence of the lower-frequency bands (557–457 cm^{-1}) reflects structural rearrangements in the fungal cell wall and supports the formation of Pb–O linkages, which commonly appear in the metal–ligand vibration range of the spectrum.

The disappearance of these peaks confirmed that the functional groups originally responsible for these vibrations were chemically altered or masked by Pb (II) binding, thereby serving as strong evidence of biosorption activity.

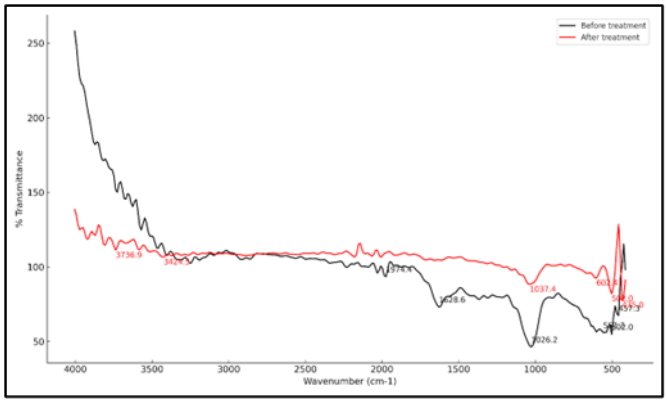

Figure 6 FTIR spectra of *G. lucidum* biomass before and after Pb (II) adsorption showing functional group involvement in biosorption

G. lucidum has a strong biosorption capacity for mercury, achieving 88.39% removal [14]. However, its biosorption performance for Pb (II) was even greater, with a removal efficiency of 91.65%. Thus, among the two metals examined, Pb (II) exhibited the highest overall removal efficiency.

3.8. Langmuir Adsorption Model

In batch experiments, adsorption isotherms were used to evaluate the adsorption characteristics. The Langmuir model is suitable for describing metal ion biosorption by fungal biomass. It can be expressed using Eq. 3.

$$\frac{q_e}{q_{max}} = \frac{K_L\ C_e}{1 + K_L\ C_e} \text{.....(Eq.3)}$$

where: (q_e) is the amount of adsorbate adsorbed per unit mass of adsorbent at equilibrium (mg/g), (q_m) is the maximum adsorption capacity of the adsorbent (mg/g), (C_e) is the equilibrium concentration of the adsorbate in the solution (mg/L), (K_L) is the Langmuir adsorption constant related to the affinity between the adsorbent and adsorbate (L/mg) [15]. The Langmuir adsorption isotherm for Pb (II) biosorption by *G. lucidum* biomass is illustrated in Fig 7.

An adsorption isotherm is used to study the interaction between metal ions and adsorbents, providing a relationship between the concentration of metal ions in a solution and the amount adsorbed onto the solid phase at equilibrium. According to the Langmuir adsorption model, adsorption occurs at a finite number of well-defined sites on the adsorbent, where each site can accommodate only one molecule [16].These sites are assumed to be energetically identical and sufficiently spaced to avoid interactions between molecules adsorbed at neighboring sites [17]. The Langmuir isotherm parameters obtained under varying experimental conditions are summarized in Table 6.

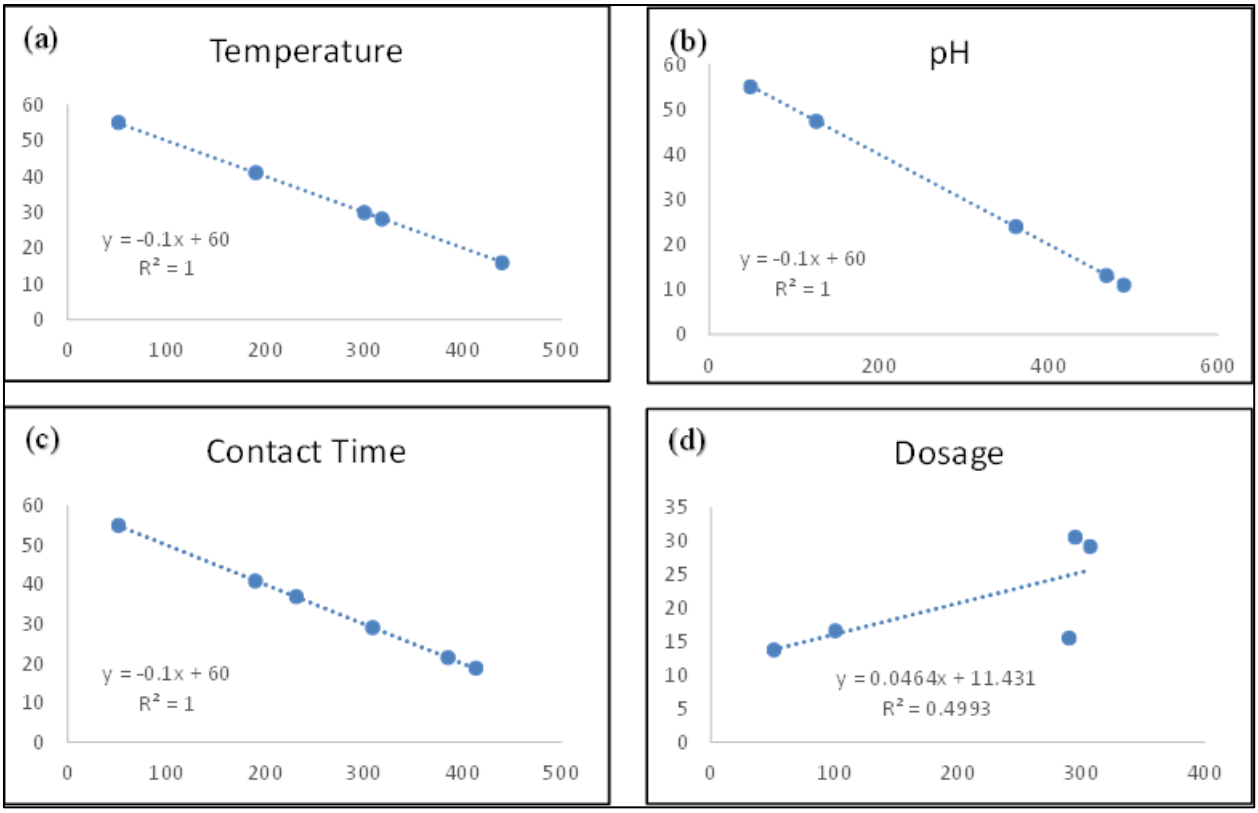

Figure 7 Langmuir adsorption isotherm plot for Pb (II) biosorption by G. lucidum biomass. (a) temperature, (b) pH, (c) contact time, (d) dosage

Table 6 Langmuir isotherm parameters for Pb (II) biosorption under different experimental conditions

Parameter	Qmax (mg/g)	KL (L/mg)
Contact Time	55.669	0.1796
pH	64.652	0.1547
Temperature	60.509	0.1653
Adsorbent Dosage	31.776	0.6782

The Langmuir adsorption isotherm was applied to evaluate the biosorption of metal ions under varying experimental conditions, including contact time, pH, temperature, and adsorbent dosage. Under varying contact times, pH values, and temperatures, the model yielded the following parameters: contact time (Qm = 55.669 mg/g, KL = 0.1796 L/mg), pH (Qm = 64.652 mg/g, KL = 0.1547 L/mg), and temperature (Qm = 60.509 mg/g, KL = 0.1653 L/mg). These results indicate that contact time, pH, and temperature moderately influence adsorption, with Qm values suggesting a reasonable monolayer adsorption capacity and KL values reflecting a moderate affinity between the adsorbent and metal ions. Among these factors, pH produced the highest adsorption capacity, likely due to its effect on the surface charge and ionization state of the adsorbate, while temperature slightly enhanced Qm, indicating mild endothermic behavior.

When the adsorbent dosage was varied, the Langmuir parameters were Qm = 31.776 mg/g and KL = 0.6782 L/mg. A higher KL demonstrates an enhanced binding affinity between metal ions and the adsorbent surface, whereas a lower Qm reflects a typical reduction in the adsorption capacity per gram of adsorbent owing to increased site availability and distribution effects.

Overall, the results show that both Qm and KL vary with the experimental conditions of the study. The pH exerted the greatest influence on the adsorption capacity, whereas the adsorbent dosage had the strongest effect on adsorption affinity. Contact time and temperature moderately contributed to the adsorption performance, indicating that optimizing the pH and adsorbent dosage is crucial for maximizing the biosorption efficiency.

4. Conclusion

This study demonstrates the significant potential of *G. lucidum* as an effective, sustainable, and eco-friendly biosorbent for the removal of lead ions from aqueous environments. Across a series of controlled batch experiments, the macrofungus exhibited a maximum removal efficiency of 91.65% under optimized conditions (600 ppm Pb (II) concentration, pH 4, 5 g biomass dosage, 24-hour contact time, and 30 ± 1°C). These findings confirm the high metal-binding capability of *G. lucidum*, which outperforms its previously reported biosorption efficiency for other heavy metals, such as mercury.

FTIR analyses provided strong evidence that functional groups, such as hydroxyl, amine, carbonyl, and polysaccharide-linked oxygen, actively participate in the biosorption of Pb (II). The appearance, shifting, and disappearance of key spectral peaks after metal exposure indicate structural and chemical modifications within the fungal cell wall, confirming the formation of Pb–O complexes and other metal–ligand interactions.

Langmuir isotherm modeling further supported the monolayer adsorption behavior of the biomass, with pH emerging as the most influential factor affecting maximum adsorption capacity. Variations in contact time, temperature, and biomass dosage also demonstrated measurable effects on biosorption performance, with higher dosages enhancing the adsorption affinity while reducing the adsorption capacity per unit mass.

Overall, the results highlight *G. lucidum* as a promising biosorbent for lead-contaminated water treatment applications. Its high adsorption efficiency, natural abundance, low cost, and environmental compatibility make it a strong candidate for integration into sustainable remediation technology. Future research should focus on kinetic modeling, regeneration studies, column-scale applications, and performance evaluations in real wastewater systems to further enhance the practical deployment potential.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

All authors declare that they have no conflict of interest or competing interests related to this manuscript.

References

[1] Generalova A, Davidova S, Satchanska G. The Mechanisms of Lead Toxicity in Living Organisms. JoX. 2025 Sept 11;15(5):146.

[2] Chavan A, Khan A, Ansari A, Kakde U. Phytoremediation of mercury using Cymbopogon citratus: Growth performance & bioaccumulation study. 2025;13(2):735–46.

[3] Thürmer K, Williams E, Reutt-Robey J. Autocatalytic oxidation of lead crystallite surfaces. Science. 2002;297(5589):2033–5.

[4] Goyer RA. Lead toxicity: From overt to subclinical to subtle health effects. Environmental Health Perspectives. 1990;86(1):177–81.

[5] Najeeb U, Ahmad W, Zia MH, Zaffar M, Zhou W. Enhancing the lead phytostabilization in wetland plant Juncus effusus L. through somaclonal manipulation and EDTA enrichment. Arabian Journal of Chemistry. 2017;10(2014):S3310–7.

[6] Fariba Mohsenzadeh ACR and MA. Evaluation of oil removal efficiency and enzymatic activity in some fungal strains for bioremediation of petroleum-polluted soils. Iranian Journal of Environmental Health Science & Engineering. 2012;9(1).

[7] Wadhwa N, Mathew BB, Jatawa SK, Tiwari A. Lipid peroxidation: Mechanism, models and significance. International Journal of Current Science. 2012;3:29–38.

[8] Paknikar KM, Puranik P. Biosorption of metals from solution by micelial waste of Penicillium chrysogenum. 2013;(December).

[9] Akar T, Tunali S, Çabuk A. Study on the characterization of lead (II) biosorption by fungus Aspergillus parasiticus. Applied Biochemistry and Biotechnology. 2007;136(3):389–405.

[10] LiuTing, Li ÆH, Li ÆZ, Xiao Æ Xiao, Chen Lingli, Deng Æ Le. Removal of hexavalent chromium by fungal biomass of Mucor racemosus : influencing factors and removal mechanism. 2007;1685–93.

[11] Das SK, Das AR. A Study on the Adsorption Mechanism of Mercury on Aspergillus versicolor Biomass. 2007;8281–7.

[12] Ozsoy HD. Biosorptive removal of Hg (II) ions by Rhizopus oligosporus produced from corn-processing wastewater. 2010;9(51):8783–90.

[13] Song Wang Xue, Yan Li Fei, Wen He, Miao HH. Hg (II) Removal from Aqueous Solutions by Bacillus subtilis Biomass. 2010;38(1):44–8.

[14] Aafrin KA, Chavan A, Awale S, Jaya P, B. KU. A study to evaluate *Ganoderma lucidum's* ability to remove mercury from water. Ecology, Environment and Conservation. 2025;31(2):718–24.

[15] Taylor P, Say R, Nalan Y, Denizli A. Separation Science and Technology Biosorption of Cadmium , Lead , Mercury , and Arsenic Ions by the Fungus Penicillium purpurogenum. 2014;(October 2014):37–41.

[16] Sen M, Dastidar MG. Biosorption of cr (vi) by resting cells of. Iran J Environ Health Sci. 2007;4(1):9–12.

[17] Febrianto J, Natasia KA, Jaka Sunarso, Yi-Hsu Ju, nani indraswati, suryadi ismadji. Equilibrium and kinetic studies in adsorption of heavy metals using biosorbent: A summary of recent studies. Journal of Hazardous Materials. 2009;162(2–3):616–45.