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REMOVAL OF Pb²⁺ AND Cr³⁺ USING RICE HUSK AS BIOSORBENT

Mahmoud S.M. Abd El-Aziz*, R.A. Al-Masry, H.T. Hefnawy and A.O.M. Khalil

Biochem. Dept., Fac. Agric., Zagazig Univ., Egypt

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ABSTRACT: The biosorption process and agricultural waste to treat heavy metals has drawn much attention. This method seems to be a more economical, environmentally friendly, and simple way for removing heavy metals from effluents. The study was conducted to explore the efficiency of the biosorption process utilizing rice husk to remove Pb²⁺ and Cr³⁺ from synthetic wastewater. Biosorption studies at different operating parameters, such as biosorbent dosage (0.5-5.0 g), pH (pH2–8), contact time (15-120 minutes), and initial heavy metal concentration (10-100 mg/L), were conducted in batch experiments. The highest performance for Pb²⁺ and Cr³⁺ biosorption was found at 5.0g biosorbent dosage of spent mushroom compost, unadjusted pH 6, 10 minutes of contact time, and 10 mg/L of initial concentration. The study was well fitted to the Langmuir isotherm model ($R^2 > 0.90$) for Pb²⁺ and Cr³⁺ biosorption, which are much greater compared to the Freundlich model. Solvent of 0.1N Sulphuric acid showed higher desorption of Pb²⁺ (89%) and Cr³⁺ (86%) adsorption-desorption process can be continued till seven cycles efficiently. In conclusion, the rice husk has the potential to be an effective biosorbent for removing Pb²⁺ and Cr³⁺ from synthetic wastewater.

Key words: Biosorption; Pb²⁺; Cr³⁺; rice husks; wastewater.

INTRODUCTION

Heavy metals are persistent contaminants in the ecosystem because they cannot be eliminated. Most heavy metals are known to be toxic and carcinogenic. Heavy metals can be released by natural processes as well as anthropogenic activities into the environment. Heavy metals are natural elements in the earth's crust and are mostly found in soils, rocks, sediments, and waters with natural background concentrations (Mohammed *et al.*, 2011). Acidification, erosion, and weathering phenomena are natural processes that bring heavy metals into the environment (Paul, 2017).

Meanwhile, anthropogenic activities such as agricultural activities, domestic waste, industrial processes, landfills, sewage discharge, mining, and emissions from vehicles also contribute to the existence of heavy metals in the environment (Elgarahy *et al.*, 2021). The presence of anthropogenic heavy metals far outweighs in terms of quantity and concentrations

compared to the natural processes (Mudhoo *et al.*, 2012). Amongst the above-listed anthropogenic activities, the industrial processes constitute the major contributor to heavy metals pollution due to inefficient treatment and poor management.

Eco-toxicity on living organism has become a prime concern for the last few decades. Massive urbanization are continuously releasing waste and wastewater to the ecosystem thus, causing pollution to environment and eventually toxicity to living being. The industrial effluents which contain different derivatives of heavy metals such as Cd, Pb, Ni, Cr, As, Cu, Fe etc. are continuously discharging to the ecosystem and producing a significant toxic impact on aquatic environment.

Large quantities of rice husks are available as waste from rice milling industry. According to the statistical data of Food and Agriculture Organization (FAO), the world annual paddy production is approximately 582 million tons. *Oryza sativa* L. husks (Rice husks) comprise 25

* Corresponding author: Tel. :+201024285637
 E-mail address: mahmouds3eed75@gmail.com

mass% of the rice grain, therefore, 145 million tons of rice husks residue are produced. These husks are not of commercial interest and cause serious pollution problems (**Gautam *et al.*, 2014**).

Heavy metals are essential nutrients and play a vital role in healthy lives of people; however, they are toxic in excessive concentrations. Heavy metals are generally present in vegetables, fruits and in multivitamin products. Heavy metals conductive a part of residual wastes of batteries, pesticides, alloys, textile dyes, steel (**Phuengphai *et al.*, 2021**), their higher concentrations may Pb^{2+} to allergies and cancer and also causes adverse effects on blood composition, liver, lungs, energy level, kidneys, central nervous system etc. Long-term exposure to heavy metals may Pb^{2+} to neurological, physical and muscular degenerative processes which may result in Alzheimer's disease, muscular dystrophy, Parkinson's disease, multiple sclerosis etc.

Many wastewater treatments processes have been developed to remove heavy metal ions; these methods include chemical precipitation, ion-exchange, adsorption, membrane filtration, electrochemical treatment technologies (**Zhang, 2014**), chemical oxidation or reduction, evaporation, filtration, reverse osmosis, electro deposition, coagulation (**Bashir *et al.*, 2020**), sedimentation, cementation, flocculation, solvent extraction (**Swathi *et al.*, 2014**), electrodialysis, ultrafiltration, photocatalysis, complexation and foam floatation (**Gunatilake, 2015**). The choice of method for wastewater treatment is based jointly on the concentration of heavy metals in the solution and the cost of treatment.

Recently efforts have been made to use cheap and available agricultural wastes such as coconut shell, orange peel, rice husk, peanut husk and sawdust as adsorbents to remove heavy metals from wastewater (**Sudha and Premkumar, 2016**). Biosorption is promising techniques for the removals of heavy metals from aqueous environment especially when adsorbents are derived from lignocellulosic materials, rice husks are an agricultural waste substance, structurally, consist of cellulose, hemicellulose, and lignin (**Al Moharbi *et al.*, 2020**).

Biosorption is the alternative process for treating heavy metals. It is an independent method of the physio-chemical passive metabolite by deploying biosorbent from non-living biological materials. Biosorption is a suggested heavy metal treatment process because it is an environmentally friendly, economical, efficient, and simple technique (**Javanbakht *et al.*, 2014**). Furthermore, this process is considered low-cost in operation and relatively more effective in treating heavy metals from dilute solutions or low concentrations of heavy metals (**Verma *et al.*, 2008**). An ideal biosorbent must have several characteristics, including availability in large quantities, low economic value, a high heavy metal affinity, can be reused many times (**Kurniawan *et al.*, 2011**). Rice husk is a type of residual material produced by rice husk production farms after the harvesting period of rice husk s. It is a mixture of rice husk mycelium, rubber tree sawdust, rice husk, and calcium carbonate. Rice husk farms dump approximately 24 tonnes of rice husk every month on average (**Singh *et al.*, 2003**). For rice husk farmers, disposing of unused rice husk is a major issue. Thus, using rice husk as a biosorbent appears to be a sustainable solution to treat heavy metals from industrial waste and simultaneously solving the waste issue in rice husk farms.

The study presenting to explore the effectiveness of agricultural by-products, namely rice husk, in treating Pb^{2+} and Cr^{3+} . The explicit aims of the present study are as follows: 1) to examine and optimize the biosorption efficiency at varying factors such as biosorbent dosage, pH, contact time, and initial heavy metal concentration, 2) to evaluate the isotherm for biosorption of Pb^{2+} and Cr^{3+} using rice husk.

MATERIALS AND METHODS

Sampling and Preparation of Sorbents

Sampling of adsorbents

Adsorbent preparation "Rice husk"

The rice husk was obtained from a field at Sharkia governorate. The husks were washed carefully with tap water and then deionized

water to remove particulate material from their surface. After that, they were dried in an oven at 100°C for 24 hr. The concentrations of the investigated metal ions in the filtrates were determined according to APHA (1999) by atomic absorption spectrophotometer (AAS).

Chemical composition of rice husks

Moisture, crude fat, crude protein, ash, crude fibre, cellulose and hemicellulose contents were determined in rice husks, according to AOAC (2010).

Preparation of metal solution

Stock solutions of heavy metals at 1g/L concentrations were prepared by dissolving a required quantity of Pb²⁺ and Cr³⁺. (1 g/L) was prepared of lead nitrate and chromate potassium and used for all experiments with required dilution. The pH of the solution was adjusted to required value by adding either 1 M HNO₃ or 1 M NaOH. The resulting stock solutions were stored in air tight bottle.

Biosorption experimental procedures

The studies were carried out under batch experiments and were performed by filling conical flasks with a known quantity of biosorbent material, followed by the addition of 50 mL of heavy metal solution. The conical flasks were then placed on the orbital shaker for a predetermined contact period and operated at a speed of 125 rpm. After completion of the treatment, the biosorbent was filtered using a filter paper size of 125 mm. Then, the filtrate was analyzed using an Atomic Absorption Spectrometer (AAS). The optimum biosorption conditions were determined at varying parameters, such as biosorbent dosage, pH, contact time, and initial heavy metal concentration. Table 1 summarises the operating conditions for Pb²⁺ and Cr³⁺ biosorption employed in this study. The batch biosorption experiments for each heavy metal were conducted separately.

Scanning electron microscopy (SEM)

The Scanning Electron Microscopy (SEM), Model: Hitachi SU-1500 was used for the study of rice husks structure. The micrographs obtained before and after the adsorption of metal ions were compared to study the adsorption

efficiency. Data size was 1280x960, accelerating voltage 15000 V, deceleration voltage was 0V and emission current was 86000 nA. SEM analysis was used for the study of peanut hulls structures using high magnification, the micrographs obtained before and after the adsorption of metal ions were compared to study the adsorption efficiency.

Infrared analysis

The infrared (IR) spectrum of rice husks was determined using a Fourier transform infrared (FTIR) spectrophotometer (Spectrum One-B, Perkin Elmer, U.S.) for detection of various functional groups. The purified rice husks was ground with KBr powder and pressed into pellets for FTIR measurement in the frequency range of 4000–400 cm⁻¹ (Zhbakov *et.al.*, 1997).

Desorption study

Desorption of rice husks was studied using 7 types of solvent media including tap water, distilled water, 0.1N H₂SO₄, 0.1N HCl, 0.1N HNO₃, 0.1N NaOH and 0.1 N CH₃COOH. For this purpose, 0.5 g of saturated (with heavy metals) rice husks was taken in 100 ml of above mentioned medium and shaken at 120 rpm for 24 h.

Adsorption experiments

Batch adsorption experiments were carried out in which aliquots of 25 ml of Pb²⁺ and Cr³⁺ solutions of known concentration were poured into flask (100 mL) containing accurately weighed amounts of the adsorbents. The rice husks weight ranged from 1 to 2.0 g per 100 ml of solutions. The flasks were shaken at 120 rpm using an electric shaker for a prescribed length of time to attain equilibrium. After filtration thorough the filter paper, Pb²⁺ and ferric ions remaining in the solutions were determined by AAS. The amount of metal ion adsorbed was calculated as

$$\% \text{ Adsorption} = \frac{C_0 - C_e}{C_0} \times 100$$

Where C₀ and C_e are the initial and equilibrium concentrations of the adsorbate, respectively.

Table 1. Summary of operating conditions for Pb²⁺ and Cr³⁺ biosorption

Parameter	Operational conditions			
	Biosorbent dosage	pH	Contact time	Initial concentration
Biosorbent dosage	0.5 – 5	6	15	500
pH	2	2-8	15	500
Contact time	2	6	15-120	500
Initial concentration	2	6	15	250 - 2000

Adsorption model

The Langmuir equation (**Duddridge and Wainwright, 1981**) is in the linear form,

$$\frac{C_e}{x/m} = \frac{1}{KX_m} + \left(\frac{1}{X_m}\right) C_e$$

Where x/m represents the amount of metal ions adsorbed at equilibrium, C_e are the equilibrium concentrations, X_m and K are Langmuir constants related to maximum adsorption capacity (monolayer capacity) and energy of adsorption, respectively. Langmuir isotherm was obtained from the experiments.

Analysis

Collected water samples from different experiments were filtered with filter paper (Whatmann 5) and prepared for AAS analysis. The samples were analyzed in term of heavy metals by Atomic Absorption Spectrometer (AAS 932 plus, GBC, Australia). The pH was measured by Hanna HI 9025 (HANNA Instrument, Romania) pH meter. Extracted rice husks and heavy metal loaded rice husks were characterized by FT -IR spectroscopy.

RESULTS AND DISCUSSION

Chemical Composition of Rice Husks

The chemical composition of rice husks is summarized in (Table 2). Data showed that rice husks composition was, organic matter 92%, ash content 3.8%; crude protein 5.4%; crude fat 0.1%; lignin 36.1%; hemicellulose 5.6% and cellulose 44.8%. The obtained results are in accordance with those of **Ismail and Waliuddin (1996)**. **Basso et al. (2002)** who reported that there was a correlation between lignin content of several lignocelluloses and their ability to remove heavy metals from aqueous solutions, therefore the high content of cellulose and lignin

observed in the tested rice husks favour biosorption of metal ions. Moreover, lignocellulosic materials are very porous, have a very high specific surface area and affinity for water (**Pehlivan et al., 2008**), which improve the performance of these materials as sorbents. Cellulosic surface becomes partially negatively charged when immersed in water so that possesses columbic interaction with cationic species, which contributes to the high binding abilities of these materials, especially divalent metal cations (**Laszlo and Dintzis, 1994**). The oxygen of each carbonyl (present in fats, lignin, protein and pectin) and hydroxyl group (present in cellulose and lignin) are considered a strong Lewis base because of the presence of its vacant double electrons, which could bind to a metal cation forming a complex of coordination.

Characterization of Rice Husk

Fourier transform infrared (FTIR) spectrometer was obtained to characterize surface functional groups of rice husk before and after adsorption process. Figs (1a,b and c) represent Fourier transform infrared spectrum of rice husk which compared with IR spectrum of heavy metals; Pb²⁺ and Cr³⁺ sorbed species. The bands absence and appearance of other bands were taken as a strong evidence for adsorption process for Pb²⁺ and Cr³⁺.

The surface morphology of rice husk before and after adsorption was visualized using scanning electron microscopy (SEM). Fig. 1.a indicated a heterogeneous, rough, and groove-like morphology. In addition, many pores on the surface of rice husk were observed. Heavy metals; Pb²⁺ and Cr³⁺ adsorbed on rice husk surface the progressive changes and the presence of new uneven bulky particles over the surface which were absent before loading the heavy metals. Many pores were also present on surface of adsorbent which favor adsorption of heavy metals (FigS. 1, b and c)

Table 2. Chemical composition of rice husks

Components	Organic matter	Ash	Crude protein	Crude fat	Lignin	Hemicellulose	Cellulose
Concentration %	92	3.8	5.4	0.1	36.1	5.6	44.8

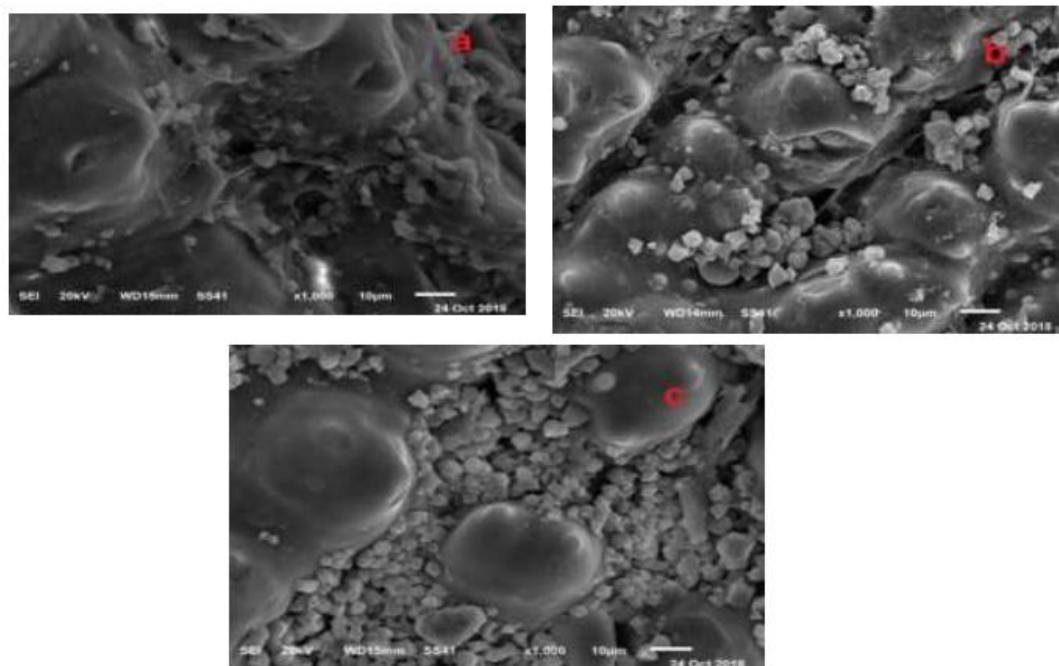


Fig. 1.a. SEM of rice husk before adsorption, Fig. 1.b. SEM of rice husk after adsorption of Pb^{2+} and Fig. 1.c. SEM of rice husk after adsorption of Cr^{3+}

Fourier Transform Infrared Spectroscopy Analysis (b), Before and After Adsorption

In order to characterize the active surface functional groups of the biochar that may participate in the adsorption of heavy metal ions from aqueous solutions, Fourier transform infrared (FTIR) spectra were recorded between 4000 cm^{-1} and 600 cm^{-1} by using a ZnSe attenuated total reflection (ATR) crystal with a Bruker Alpha-E spectrometer. Figure 2b shows the various functional groups present on the surface of the biochar before and after adsorption of Pb^{2+} and Cr^{3+} . The rice husks peel consists of carbohydrates, fiber, proteins, lipids, N–H, O–H, and Si–O functional groups, aliphatic groups, and aromatic rings that are all responsible for adsorption (Aslam *et al.*, 2004). As shown in Fig. 2b, the peaks in the spectra between 600 and 700 cm^{-1} mainly arise from

out-of-plane vibrations of the C–H bond in aromatic and heteroaromatic compounds (László *et al.*, 2000). Peaks at 826 and 980 cm^{-1} could be the result of the concentration of alkaline earth elements with the peak at 826 cm^{-1} assigned to the C–H out of-plane bending of an aromatic ring (DeMessie *et al.*, 2015). The peak at 1250 cm^{-1} suggests the presence of a hydrogen-bonded hydroxyl compound (Karim *et al.*, 2015). The peak at 1400 cm^{-1} could be assigned to CO_2 . The presence of a carbonyl group at 1600 cm^{-1} was also reported for a heated cellulose carbon, and the peak at 1613 cm^{-1} may correspond to $-COO-$ groups and can be assigned to $-C=C-C$ stretches of aromatic ring groups. This indicates the increased stability of rice husks biochar when compared to rice husks that is due to thermochemical biomass conversion (Yang *et al.*, 2015).

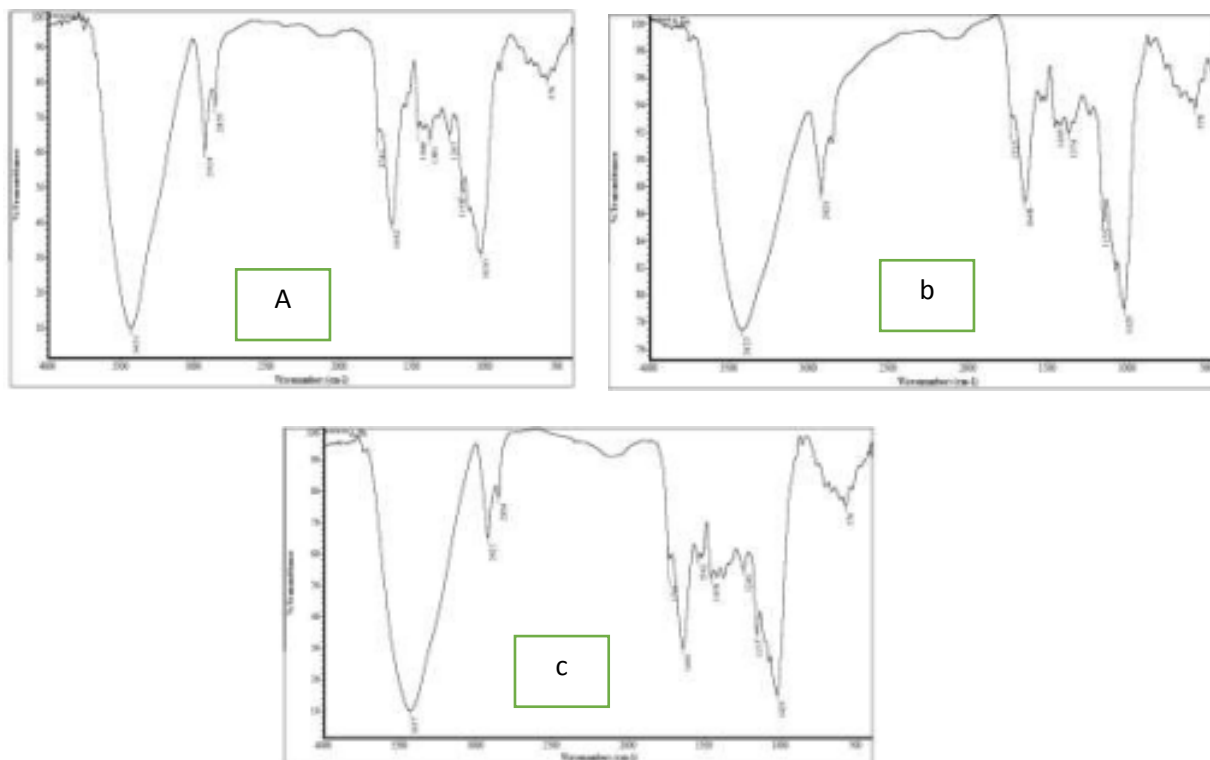


Fig. 2a. FTIR for rice husk. Fig. 2b. FTIR for rice husk after adsorption of Pb^{2+} . Fig. 2c. FTIR for rice husk after adsorption of Cr^{3+}

Effect of Adsorbent Weight

The weight of rice husks adsorbent varied from 0.5 to 6g all the other experimental variables were kept constant pH 6 initial concentration 50 mgL^{-1} , and contact time 90 min. The removal of Pb^{2+} and Cr^{3+} under adsorbent weight effect (Fig. 3) indicated that, the removal percentage decreased with decreasing the adsorbent weight, until equilibrium at 5g. **Bhatti *et al.* (2007)** showed that, by increasing the adsorbent weight the functional groups on it increased, these groups were necessary during adsorption process in the formation of Vander Waals bonding. This give more possibilities for adsorption of metals and less competition between metals and the binding sites.

Effect of Temperature

The range of temperature from 25 to 45 °C and optimum parameters are pH, adsorbent dose, initial ion concentration, agitation time and agitation speed were kept at 6, 5g, 50 mg/l,

90 min, 150 rpm, respectively. As seen in (Fig. 6) the effect of temperature on the removal of Pb^{2+} and Cr^{3+} by rice husks were 90%, 92% and 89%, respectively. All the metals follow the same trend that, the removal percent increased by decreasing temperature, the results agree with **Bhatti *et al.* (2007)** who found that, there is a reverse relationship between the % of removal and temperature.

Effect of pH

The highly crucial factor regulating heavy metal biosorption is pH. Contrasts in pH straightforwardly influence the serious capacity of hydrogen ions with heavy metal ions at the dynamic binding sites on the biosorbent surface (**Zhang *et al.*, 2014**). The influence of pH on Pb^{2+} and Cr^{3+} biosorption was studied in the pH range of 2 to 8. Fig. 4 presents the Pb^{2+} and Cr^{3+} biosorption results with varying pH values. The performance of Pb^{2+} and Cr^{3+} biosorption improved as the pH value raised from pH 4 to 5. The highest biosorption efficiencies for both heavy metals were found at pH 6, 40.12%, and

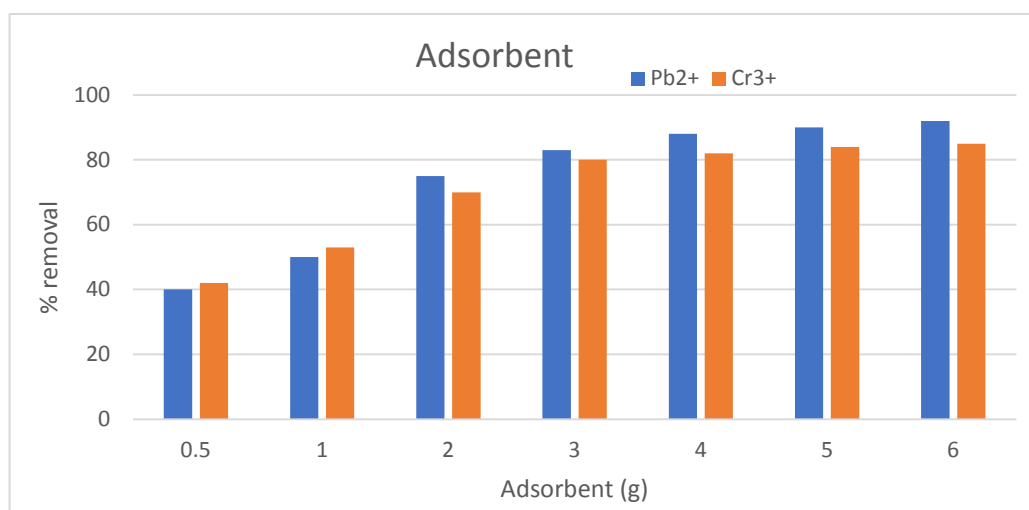


Fig. 3. Effect of adsorbent weight on the removal of Pb²⁺ and Cr³⁺ using rice husks adsorbent

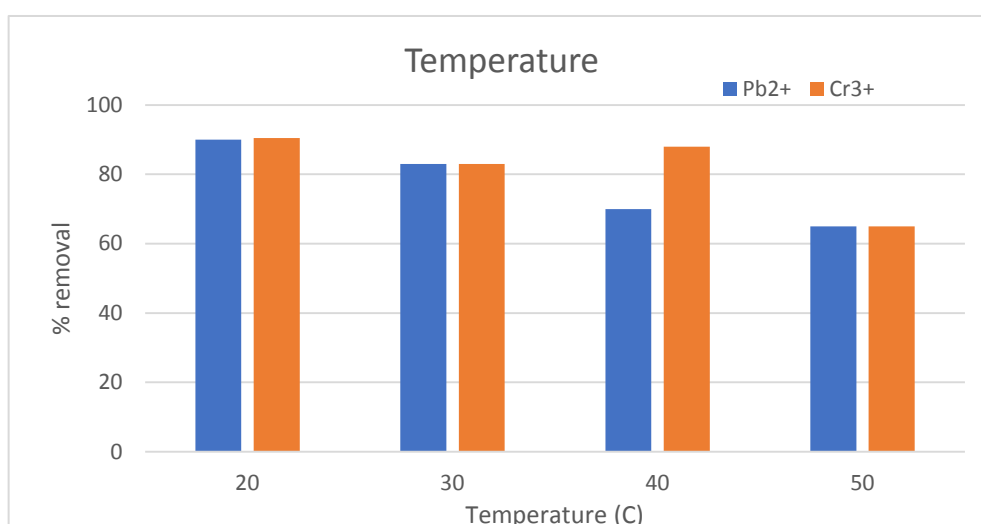


Fig. 4. Effect of temperature on the removal of Pb²⁺ and Cr³⁺ using rice husks adsorbent

63.24% for Pb²⁺ and Cr³⁺, respectively. Then, the highest uptake capacity for Pb²⁺ was observed at 0.70 mg/g, while for Cr³⁺, it was at 0.62 mg/g. At pH 7 to 8, the uptake capacity for both heavy metals decreased. The low uptake capacity at low pH could be because the biosorbent surface is protonated and acts as a positive charge (Tay *et al.*, 2012). Therefore, the charge repulsion formed and decreased biosorption uptake of Pb²⁺ and Cr³⁺ (Najim *et al.*, 2009). Meanwhile, when pH is raised, the binding sites on the biosorbent's surface deprotonate, and the charge attraction is reinforced (Sathasivam *et al.*, 2010).

Consequently, Pb²⁺ and Cr³⁺ biosorption uptake increased significantly. Similar trends were observed pine fruit (Najim *et al.*, 2009), rice husks trunks (Ketsela *et al.*, 2020) and white lupine husk (Fathollahi *et al.*, 2021) to treat Pb²⁺ and/or Cr³⁺.

Effect Contact Time

The effects of contact time on heavy metals removal (Fig. 5) gave removal % as 92 for Pb²⁺ and 75 for Cr³⁺ and the equilibrium was at 90 min. Generally, with increasing the contact time removal percentage was increased, the heavy metals removals follow the order Pb²⁺ > Cr³⁺.

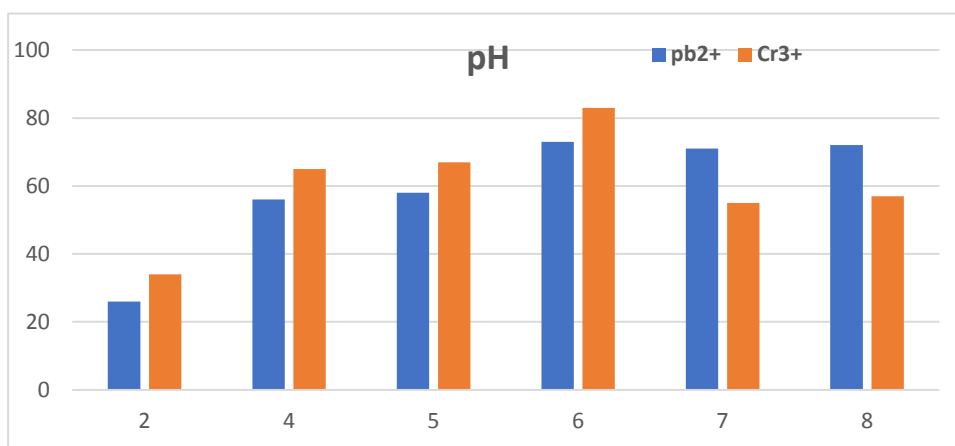


Fig. 5. Pb²⁺ and Cr³⁺ biosorption versus pH

This may give an indication that the adsorption process could happen in a single step (Mishra and Tiwari, 2002). Scott *et al.*, (1995) explained that, in the initial stage of the adsorption process, adsorptive ions occupy active surface sites because the surface coverage is low causing higher uptake rate. The surface coverage is increased by time Pb²⁺ ioning to decrease in the uptake rate until the surface becomes saturated.

Initial Heavy Metals Concentration

Fig. 6 depicts the influence of different concentrations on Pb²⁺ and Cr³⁺ biosorption. The Pb²⁺ and Cr³⁺ biosorption gradually decreased from 55.22% to 23.48% and 61.71% to 29.10%, respectively, when the initial concentration of both heavy metals was increased between 10 to 100 mg/L. The highest uptake capacities of Pb²⁺ and Cr³⁺ were obtained at 0.22 mg/g and 0.31 mg/g, respectively. The decrease in biosorption efficiency was probably due to the saturation of the binding sites on the surface of the biosorbent with more heavy metal ions in the solution (Rizzuti *et al.*, 2021). After all, the percentage removal of heavy metals was observed with higher biosorption levels at lower heavy metal concentrations (Vijayaraghavan *et al.*, 2006). This occurs because at a lower initial heavy metals concentration, the ratio of the initial moles of heavy metals to the available binding sites is low, and thus, adequate binding sites are available to accommodate all the heavy metals ions (Ansari *et al.*, 2011). On the other hand, the biosorption uptake capacity enhanced with increasing initial heavy metals concentration due to the high concentration gradient between the heavy metals on the biosorbent and the heavy

metals in the solution. A large concentration gradient is a driving force in overcoming the resistance of pollutant mass transfer between the aqueous and solid phases. This result will Pb²⁺ to an increase in heavy metals uptake (Han *et al.*, 2011). Similar findings have been observed in other studies, such as pine cone powder (Mzinyane *et al.*, 2021) and pumpkin stem (Reddy *et al.*, 2021) as biosorbents. The results indicated that these biosorbents have great potential as an optional treatment for removing heavy metals from effluents.

Desorption Performance

Desorption of metals or regeneration of adsorbents from used-adsorbents are crucial to repeat the use of adsorbents, recover of precious metals and reduce the cost of operation in any water treatment system. The adsorbed metals on adsorbents can not be completely reversible as reported by several observations on literature (Ainsworth *et al.*, 1994). Eight solvent were used for desorption/regeneration experiment and the results are presented in Fig. 8. Among the solvents the tap water, distilled water, CH₃COOH and NaOH were resulted a limited amount of metals ion recovery (<30%). The highest (94%) recovery was found with the use of 0.1N H₂SO₄. The other two acids 0.1 N HCl and 0.1 N HNO₃ were shown lower efficiencies (54 and 72%). In the desorption system H⁺ released from the acids which replaced metal cation (heavy metals, Pb²⁺ and Cr³⁺) on the surface of the rice husks (Karthikeyan *et al.*, 2007). The recovery and reuse processes for rice husks can be continued up to 10 times with minor deviation in removal efficiency.

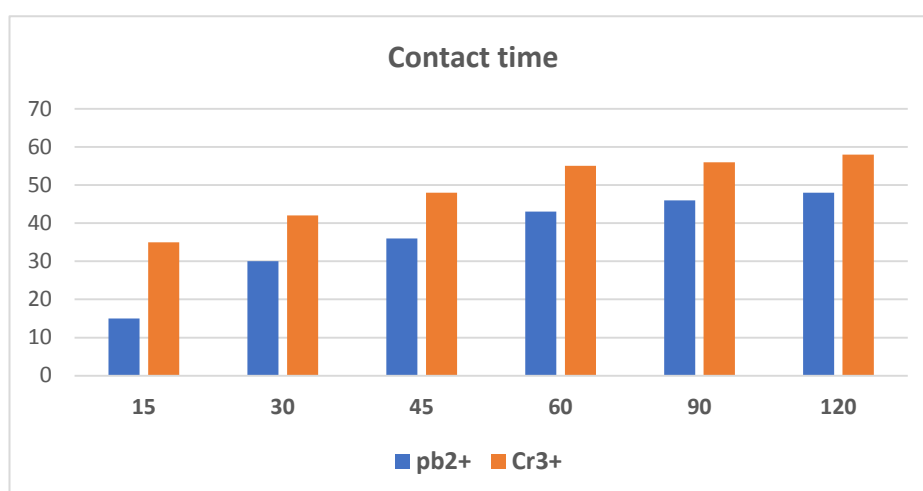


Fig. 6. Effect of contact time on the removal of Pb²⁺ and Cr³⁺ using rice husks adsorbent

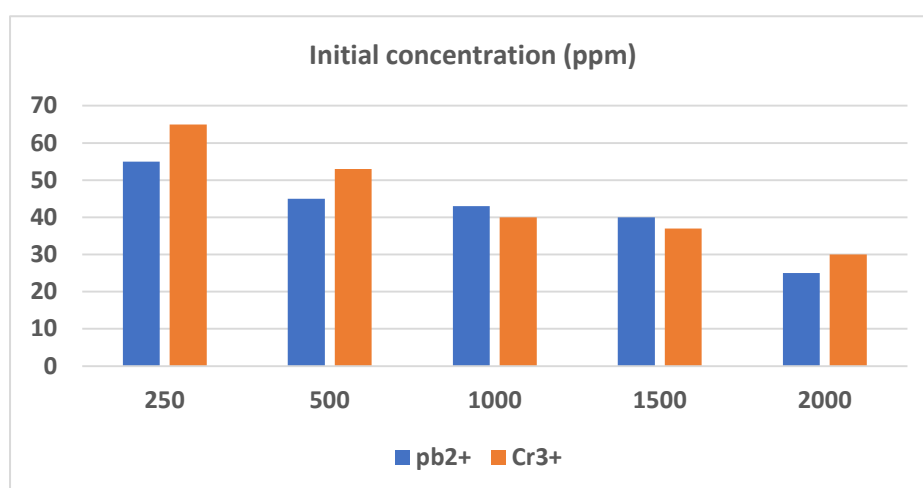


Fig. 7. Pb²⁺ and Cr³⁺ biosorption versus initial concentration

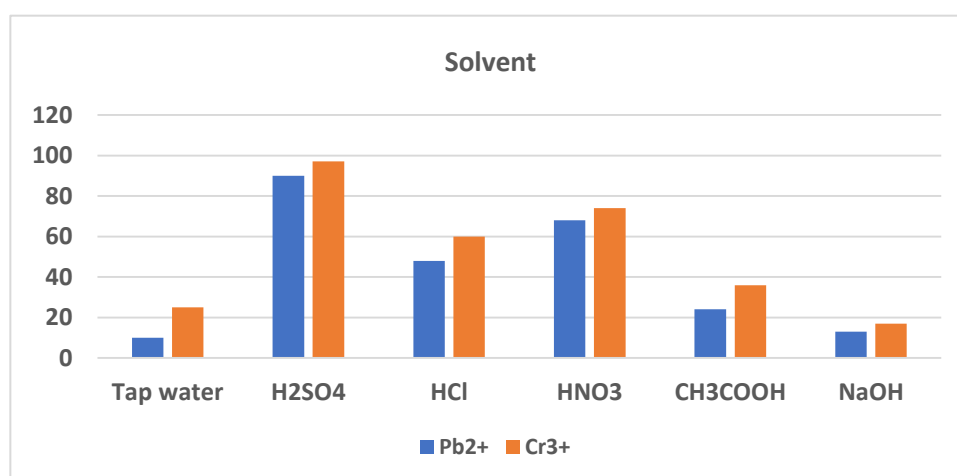


Fig. 8. Desorption of heavy metals Pb²⁺ and Cr³⁺ (from rice husks (Co: 10 mg/l; desorption time: 24h; rpm: 120; T: 20°C)

Evaluation of Existing Mathematical Models

The Pb^{2+} and Cr^{3+} biosorption experimental data were also assessed using isotherm models (Langmuir and Freundlich isotherms), regression analysis using the linearized equation of Langmuir model for Pb^{2+} and Cr^{3+} was established in Fig. 9. The linearisation of the Langmuir model helps estimate constant parameters such as maximum sorption capacity, q_e , and the Langmuir constant, b , whereas the Freundlich model provides information about n and K_f values, which represent binding energy and bond strength, respectively (Shukla *et al.*, 2013). Table 3 summarises the constant parameters of the Langmuir models. The findings indicated the

experimental data were well fitted to the Langmuir biosorption isotherms model for Pb^{2+} and Cr^{3+} biosorption since the coefficient of determination, R^2 values were higher than the Freundlich model. These results suggest that the Pb^{2+} and Cr^{3+} biosorption on the surface of rice husk occurred in monolayer biosorption (Alomá *et al.*, 2012). It has been widely known that the Langmuir biosorption isotherm assumes that biosorption occurs at specific sites within the surface of biosorbent. Therefore, there is no further binding process at active sites once they are occupied. The finding is consistent with other biosorbents such as red mud (Nadaroglu *et al.*, 2010) for Pb^{2+} removal and durian leaves for Cr^{3+} removal (Abood *et al.*, 2015), which also fitted the Langmuir model.

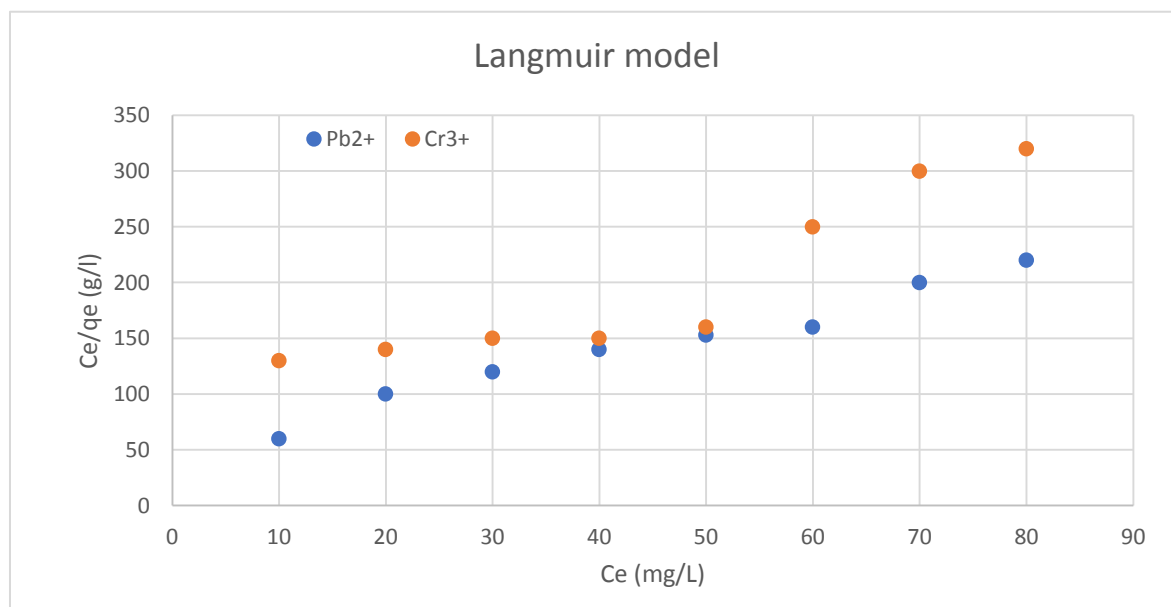


Fig. 9. Evaluation of Pb^{2+} and Cr^{3+} biosorption using the Langmuir model

Table 3. Isotherm constant parameters for Pb^{2+} and Cr^{3+} biosorption

Heavy metal	Q(mg/g)	B(L/mg)	R^2
Pb^{2+}	0.34	0.04	0.9452
Cr^{3+}	0.43	0.04	0.9756

Conclusions

Lead and chromate ions biosorption using rice husk was investigated in batch experiments with varying operating conditions. The experimental investigations indicated the Pb^{2+} and Cr^{3+} biosorption are highly influenced by the amount of biosorbent, pH, contact time, and initial heavy metal concentration. The best operating parameters to achieve higher efficiency for Pb^{2+} and Cr^{3+} biosorption were obtained using 5.0 g of biosorbent amount, pH of 6, 10 min of contact time, and 10 mg/L of initial concentration. The biosorption isotherm and kinetic of rice husk biosorbent were also determined throughout this study. The coefficient of determination ($R^2 > 0.90$) for Pb^{2+} and Cr^{3+} biosorption indicated that the results adapted fit to the Langmuir isotherm. This implies that the biosorption mechanism for Pb^{2+} and Cr^{3+} ions into rice husk is accompanied by a monolayer pattern. The rice husk biosorbent is appropriate for use in the biosorption process. Therefore, rice husk biosorbent has a high chance of reducing solid waste management problems related to rice husk cultivation farms.

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إزالة كاتيون الرصاص (II) وكاتيون الكروم (III) باستخدام قشر الأرز

محمود سعيد محمد عبد العزيز - رجب عبدالفتاح المصري - حفناوي طه حفناوي - علي عثمان محمد عثمان

قسم الكيمياء الحيوية - كلية الزراعة - جامعة الزقازيق- الزقازيق-مصر

لقت تطبيق عملية الامتصاص الحيوي والمخلفات الزراعية لمعالجة المعادن الثقيلة الكثير من الاهتمام. وهذه الطريقة طريقة أكثر اقتصادا، وصديقة للبيئة، وبسيطة لإزالة المعادن الثقيلة من النفايات السائلة. أجريت الدراسة لاستكشاف كفاءة عملية الامتصاص الحيوي باستخدام قشر الأرز لإزالة كاتيون الرصاص وكاتيون الكروم من مياه الصرف الصناعي. كانت دراسات الامتصاص الحيوي عند معايير تشغيل مختلفة، مثل جرعة الامتصاص الحيوي (0.5-5.0 جم)، ودرجة الحموضة (الرقم الهيدروجيني 2-8)، ووقت التلامس (15-120 دقيقة)، والتركيز الأولي للمعادن الثقيلة (250-2000 مجم/لتر)، كانت أجريت في تجارب دفعية. تم العثور على أعلى أداء للامتصاص الحيوي كاتيون الرصاص وكاتيون الكروم عند 5.0 جرام من جرعة الامتصاص الحيوي من قشر الأرز، ودرجة الحموضة 6 و 30 دقيقة من وقت التلامس، و 500 مجم/لتر من التركيز الأولي. كانت الدراسة مناسبة بشكل جيد لنموذج لبيرمان ($R^2 > 0.95$) للامتصاص الحيوي كاتيون الرصاص وكاتيون الكروم. أظهر مذب حمض الكبريتيك N0.1 امتصاص أعلى للرصاص (II) (90%) والكروم (III) (88%) يمكن أن تستمر عملية الامتصاص والامتصاص حتى سبع دورات بكفاءة. في الختام، قشر الأرز لديه القدرة على أن يكون عاملاً حيويًا فعالاً لإزالة كاتيون الرصاص و كاتيون الكروم من مياه الصرف الصناعي.

المحكمون:

1- أستاذ الكيمياء الحيوية ووكيل الكلية لشئون البيئة- كلية التكنولوجيا والتنمية- جامعة الزقازيق.
2- أستاذ كيمياء حيوية -ووكيل الكلية لشئون التعليم والطلاب- كلية الزراعة - جامعة الزقازيق.

1- أ.د. جيهان عبدالعزيز السيد
2- أ.د. خالد محمد محمد وهدان