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Coffee Husk and Coffee Ground as an Adsorbent for the Removal of Lead, Copper and Chromium from Aqueous Solution

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Abstract
This study aimed to investigate the removal efficiency of coffee husk and coffee ground adsorbents to adsorb lead(II), copper(II), and chromium(VI) from an aqueous solution. Standard lead nitrate, potassium dichromate, and copper chloride solutions were prepared following standard laboratory procedures. The residual metallic ion concentrations were determined using Atomic Absorption Spectrometer (AAS). The experimental parameters such as pH, contact time, adsorbent dosage, agitation speed and initial concentration of selected metal ions were evaluated at different particle size fractions (>200 μm and <200 μm) of adsorbent in aqueous solutions. The results revealed that the best adsorption conditions obtained for the heavy metals removal were pH 5, at a contact time of 60 min, an adsorbent dosage of 0.5 g, an initial concentration of 0.5 mg/L, and 115 rpm agitation speed. At fractions of particle size <200 μm, the removal efficiency of adsorbents coffee husk and coffee ground were found as 94.2% and 96.5%, 97.6% and 97.6%, and 93.5% and 94.46% for lead(II), copper(II) and chromium(VI), respectively. Similarly, at the fractions of particle size >200 μm, the removal efficiency of coffee husk and coffee ground investigated were 93.2% and 96.06%, 97.2% and 83%, and 92.4% and 94.46% for lead(II), copper(II) and chromium(VI), respectively. The obtained results show that coffee husk and coffee ground adsorbents used in this study can serve as excellent bio-sorbent for efficiently removing selected heavy metals from the aqueous solutions.

Keywords: Coffee husk, Coffee ground, Adsorption, Heavy metal, Aqueous solution

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Introduction

Heavy metals are chemical elements naturally occurring in the environment. Their concentration and deposition levels have increased significantly since pre-industrial times due to anthropogenic activities causing a risk of adverse health effects in humans and wildlife [1-3]. Accelerated industrialization and urbanization have pronounced effects worldwide through the undue release of heavy metals into the environment and water sources. Lead, chromium, and copper are naturally existing substances often present within the environment and the earth's crust at low levels. Large quantities of those heavy metals released into the environment and water bodies can cause a significant health threat to the ecosystem [4]. Heavy metals have a strong affinity and make complexes with many biomolecules and adversely affect cardiovascular, nervous, gastrointestinal, reproductive, immune, skeletal and muscular systems, and DNA damage [5]. An excessive amount of commercial waste like metal plating, mining operations, battery

manufacturing processes, paints, and dye manufacturing, and ceramic and glass industries release wastewater contaminated with heavy metals into the environment [2].

Large quantities of heavy metals containing wastewater are generated with the industry's progressive development. The inadequate treatment of industrial wastewater becomes one of the critical environmental problems since heavy metals can accumulate in all living organisms. Therefore, treating metal-contaminated sewage before discharging it into the environment is needed [6]. Various methods are available to remove heavy metal ions from wastewater and aqueous solutions. These include chemical precipitation, oxidation, reduction, reverse osmosis, membrane filtration, adsorption, etc. [7, 8]. Most of the methods suffer from drawbacks such as high operational costs of materials and are not appropriate for small-scale industries. Adsorption is one of the most effective methods for removing heavy metals from wastewater and aqueous solutions owing to its ease of handling and low cost [9].

Many research results showed that papa wood, coffee husk, coffee ground, coconut core, peanut hull, and tea waste are low-cost adsorbents for heavy metals from aqueous solution [5, 10-14]. The effect of different adsorption parameters such as contact time, pH, initial concentrations of metal, and dose of the adsorbent on the removal efficiency of adsorbents have been investigated [15].

Coffee husk and coffee grounds are abundant and low-cost adsorbent materials on a large scale in many African countries, especially Ethiopia. Since Ethiopia is Africa's leading coffee producer, many coffee husks and coffee ground residues were obtained from processing units and cafeterias [14]. In the Ethiopian context, limited information exists to apply low-cost adsorbents such as coffee husk and coffee ground for toxic metal removal in environmental samples. The objective of the present study was to investigate the removal efficiency of local adsorbents coffee husk and coffee ground for lead(II), copper(II), and chromium(VI) removal from aqueous solutions.

Materials and Methods
Equipment and Apparatuses

An electronic blending device was used for grinding coffee husks and coffee ground samples. Analytical digital balance (ABS220-4) was used to weigh coffee husk and coffee ground samples, sieve size (mussizeAS200 control, Retsch) was used to measure different particle sizes, micropipette was used for measuring the different amounts of acid mixtures and standard solutions. 100 and 250 mL volumetric flasks and Erlenmeyer flasks were used to dilute sample solutions and to prepare standard solutions. The shaker (SSL2, Stuart) was used for adsorption studies. A pH meter (Jenway, 3310) was used during the pH measurement of an adsorbent. The concentration of lead(II), copper(II), and chromium(VI) in the aqueous solution was determined by atomic absorption spectrophotometers (Buck Scientific, model of AAS 210 VGP) by using hollow cathode lamps; air–acetylene flame was used for the analysis of the metals lead(II), copper(II) and chromium(VI).

Reagents and Chemicals

Analytical grade chemicals and reagents were used in this study. This includes Lead nitrate ($Pb(NO_3)_2$), Potassium dichromate ($K_2Cr_2O_7$), and copper chloride ($CuCl_2$). The standard solution for each metal was prepared using standard laboratory procedures. All the required solutions were prepared with analytical reagents, and distilled water was used throughout the experiment [2, 14, 16].

Sample Collection and Preparation

Coffee ground samples were collected after roasting for coffee drinks of Wolaita Sodo University students, and teachers' cafeteria and coffee husk from a coffee processing unit for union farmer company in a 200g package. Following laboratory procedure, the samples were bagged, labeled, and transported to the laboratory to prepare and analyze selected samples of coffee husk and coffee ground.

Preparation of adsorbents

The collected coffee husk and coffee ground samples were washed with distilled water to remove dirt and boiled to remove color [14]. After drying at 105℃, a part of the coffee ground and coffee husks were ground and sieved (sieve mesh size 200 µm). The experiments were performed using two different fractions, a particle size >200 µm and <200 µm [2]. Both fractions of coffee grounds and coffee husks were put in sealed polyethylene bags for preservation so that it does not react with the neighboring environment.

Preparation of heavy metal solutions

Analytical reagent grade lead Nitrate $(Pb(NO_3)_2)$, potassium dichromate $(K_2Cr_2O_7)$, and copper chloride $(CuCl_2)$ were dissolved in distilled water to give 1000 ml of solution (Conc. 1000 mg/L). Standard lead nitrate, potassium dichromate, and copper chloride solutions were prepared following standard laboratory procedures [2, 16].

Preparation of adsorbent for AAS analysis

0.5 g of coffee grounds and coffee husk (particle size <200 µm and >200 µm) were used as an adsorbent. In a 100 mL volumetric flask, a solution with a known concentration of lead(II), chromium(VI), and copper(II) was added in triplicate in each experiment. All these flasks were placed into a shaker with 100-130 rpm. After 1 h of contact time, the flasks' contents were filtered using filter paper (Whatman cat No, 3001-861). lead(II), chromium(VI), and copper(II) concentrations of the filtrate were determined by atomic absorption spectroscopy [2, 14].

Adsorption Experiment

The effects of different parameters such as adsorbate (lead(II), chromium(VI), and copper(II)) concentration, adsorbent (coffee husk and coffee ground) dose, agitation speed, contact time, and pH were studied. Adsorption studies were carried out using a 250 mL Erlenmeyer flask and a volumetric flask. Standard solutions of the lead(II), copper(II), and chromium(VI) were mixed with the coffee husk and coffee ground agitates at different agitation rates on a mechanical shaker [14]. Studies on the effects of different parameters were carried out by varying lead(II), chromium(VI), and copper(II) concentrations, pH, and weight of coffee husk and coffee ground used for adsorption. Finally, the resulting suspension of the metal ions was filtered using filter paper, and the concentration of heavy metal ions estimated using flame atomic absorption spectrometer (FAAS). All experiments were performed in triplicate, and data analysis considered mean values of the percentage of lead(II), chromium(VI), and copper(II) removal (%).

Effect of pH on adsorption

The optimum pH at which the maximum amount of lead(II), chromium(VI), and copper(II) adsorption by coffee husk and coffee ground were obtained by adjusting the pH of the stock solution using 0.1 M HCl, or NaOH. 0.5 g of coffee ground and coffee husk were added to the 250 mL Erlenmeyer flasks

containing 100 mL of lead(II), chromium(VI), and copper(II) solution, separately. Solution pH was adjusted from 2 to 8, the mixtures were shacked in the range of 100-130 rpm for a period of equilibrium time, and after equilibrium was reached, the final pH of the mixture was recorded. The sample was filtered, and the concentration of filtrates (lead, chromium, and copper) were measured [14].

Effect of contact time

Adsorption experiments were performed in triplicates by mixing 0.5 g/L of adsorbent with 100 mL of single metal solution (100 mg/L). The suspensions were shacked for 1 h at pH 5 (both for lead(II), copper(II), and chromium(VI)) in a water bath at 25 ℃ (agitation rate of 100-130 rpm). Samples were collected at fixed intervals (30-90 min) [16].

Effect of initial concentration

Metal adsorption was influenced by the initial concentration of metal ions in aqueous solutions. In this study, the initial metal concentration lead(II), chromium(VI), and copper(II) were varied from 0.5 to 1.5 mg/L for >200 µm and <200 µm adsorbent particle size [2].

Effect of agitation rate

The effect of agitation rate on equilibrium was observed by mixing 0.5 g of both samples (coffee husk and coffee ground) of adsorbents with 100 mL of 100 mg/L metal solutions (single-component). The suspensions were shaken for 1 h at pH 5 (both for lead(II), copper(II), and chromium(VI)) in a water bath at 25°C. The agitation rate ranged from 100-130 rpm [16].

Data analysis

One-way analysis of variance (ANOVA) was used to test differences between two or more means. The general linear model (GLM) procedure of statistical analysis system version 9.13 (SAS institution) was used as a tool for statistical analysis and to test the significant difference between treatment means and standard deviation of all data [5].

Results and Discussions
Effects of Adsorbent Particle Size

As shown in Table 1, among the particle size tested, <200 µm coffee ground (Cg) showed 96.53% maximum removal efficiency for lead. In contrast, the minimum percent removal (93.2%) of lead was obtained for particle size >200 µm coffee husk (Ch). One-way analysis of variance showed that after adsorption, the final concentration (Ce) of lead(II) for Ch > 200 µm and Ch < 200 µm are significantly different. However, Cg < 200 µm and Cg > 200 µm particle sizes were not significantly different. The results were consistent with the reported values [2].

Table 1. **Final concentration (Ce) (mg/L) after adsorption and percent removal of lead(II), copper(II) and chromium(VI).**

Particle size (µm)	Final Concentration, Ce (mg/l)			% Removal		
	Pb(II)	Cu(II)	Cr(VI)	Pb(II)	Cu(II)	Cr(VI)
Ch < 200	$0.029^b \pm 0.003$	$0.012^c \pm 0.004$	$0.033^b \pm 0.003$	$94.20^b \pm 0.20$	$97.60^a \pm 0.08$	$93.46^b \pm 0.50$
Ch > 200	$0.034^a \pm 0.004$	$0.014^c \pm 0.002$	$0.038^a \pm 0.002$	$93.20^c \pm 0.80$	$97.20^{ab} \pm 0.04$	$92.40^c \pm 0.70$
Cg < 200	$0.017^c \pm 0.001$	$0.018^b \pm 0.002$	$0.022^c \pm 0.005$	$96.53^a \pm 0.40$	$97.60^a \pm 0.31$	$95.66^a \pm 0.40$
Cg > 200	$0.0196^c \pm 0.003$	$0.085^a \pm 0.007$	$0.027^b \pm 0.003$	$96.06^a \pm 0.30$	$83.00^c \pm 1.00$	$94.46^b \pm 0.50$
LSD	9.69	0.0065	0.005	0.954	1.295	0.573
CV	0.0045	10.6	8.97	0.533	0.735	1.014

*Ce = final concentration, Ch = coffee husk, and Cg = coffee ground, LSD = Least Significant Difference, CV = Coefficient of Variation,
*Means with the same letter are not significantly different.

As presented in Table 1, among the particle sizes tested for <200 µm coffee ground and coffee husk, the maximum percentage removal of copper was 97.6% and 97.6%, respectively, whereas the minimum percent removal of copper for particle size >200 µm coffee ground was 83.0%. After adsorption, the final concentration (Ce) of Cu(II) for Cg >200 µm and Cg <200 µm are significantly different. However, Ch <200 µm and Ch >200 µm were not significantly different.

Similarly, among the particle sizes tested, <200 µm coffee ground particles have shown a maximum removal percentage of 95.66% for chromium, whereas the minimum removal percentage for coffee husks particle size >200 µm was 92.4%. After adsorption made, the final concentration (Ce) of chromium (VI) for Coffee husk >200 µm and Coffee husk <200 µm, for Coffee ground <200 µm and Coffee ground >200 µm are significantly different (Table 1).

Generally, the extent of adsorption depends on the adsorbent particle size and the initial metal concentration in the aqueous solutions. The percentage of toxic heavy metal removal was increased when the coffee husk and coffee grounds adsorbent particle size was decreased. The results showed that lower residual concentrations were obtained when the coffee ground and coffee husk were smaller particle sizes (<200 µm). The findings of this study were in line with the result investigated by [2].

Effect of pH on Adsorption

pH of an aqueous solution is one of the major controlling parameters that have a significant effect on the adsorption process [17]. The effect of pH on the degree of adsorption of lead (II), copper (II), and chromium (VI) onto the coffee husk and coffee ground was studied by varying the pH in the range of 2 to 8. The results in Fig. 1 clearly showed that lead, copper, and chromium adsorption increased with an increase in the pH between pH 2 and 5, whereas, it decreased with a further rise above pH 5. The maximum adsorption of lead(II), copper(II), and chromium(VI) was attained at pH 5.

The removal efficiency of leadII) for coffee husk and coffee ground of particle size >200 µm was 91.12% and 91.12%, respectively. Though, the removal capacity of coffee husk and coffee ground of particle size >200 µm for copper(II) was 92.9% and 94.94%, respectively. The removal efficiency of Cr(VI) for coffee husk and coffee ground of particle size >200 µm was 92.9% and 89.12%, respectively. On the other hand, the removal efficiency of coffee husk and coffee ground of particle size <200 µm for lead(II) was 93.34% and 95.56%, respectively, while the removal capacity of coffee husk and coffee ground of particle size, <200 µm for copper(II) was 84.2% and 95.04%, respectively. The removal capacity of coffee husk and coffee ground of particle size <200 µm for chromium(VI) was 92.6% and 94.2%, respectively. The obtained results were consistent with the study's findings [2, 18].

Esposito *et al.* [19] noticed that the ability to remove metal ions by adsorbent depends on the pH of a solution and this in turn depends on the ion state and nature of the material. The pH of a solution affects the concentration and solubility of metal ions of the counterions on the functional groups of the adsorbent [20, 21]. At more acidic or low pH (below 2), the presence of H^+ increased in the solution, so there was high protonation of the active sites or functional groups at the coffee husk and coffee ground surface, which forbade the formation of links between

lead(II), copper(II), and chromium(VI) ions and the active sites [22].

At moderate pH values (2 to 5), linked H^+ ion was released from the active sites, increasing the number of metal ions adsorbed. At higher pH values (above 5), the precipitation was dominant, or both ion exchange and aqueous metal hydroxide formation could become higher processes. These complexes were also rejected by the negatively charged coffee husk and coffee ground particles owing to the electrostatic repulsion, which explains the lower metal removal observed at pH values above approximately. The result was consistent with the findings by [2, 14]. Another report on the adsorption characteristic studies of the metal ions by Habib et al. [23]; Elliot and Huang [24] indicated that the maximum adsorption efficiency investigated in the pH range of 2-10 may be due to the interaction of metal ions with functional groups or active sites present in the surface of the adsorbent and it decreases at higher pH this may due to the formation of soluble hydroxy complexes.
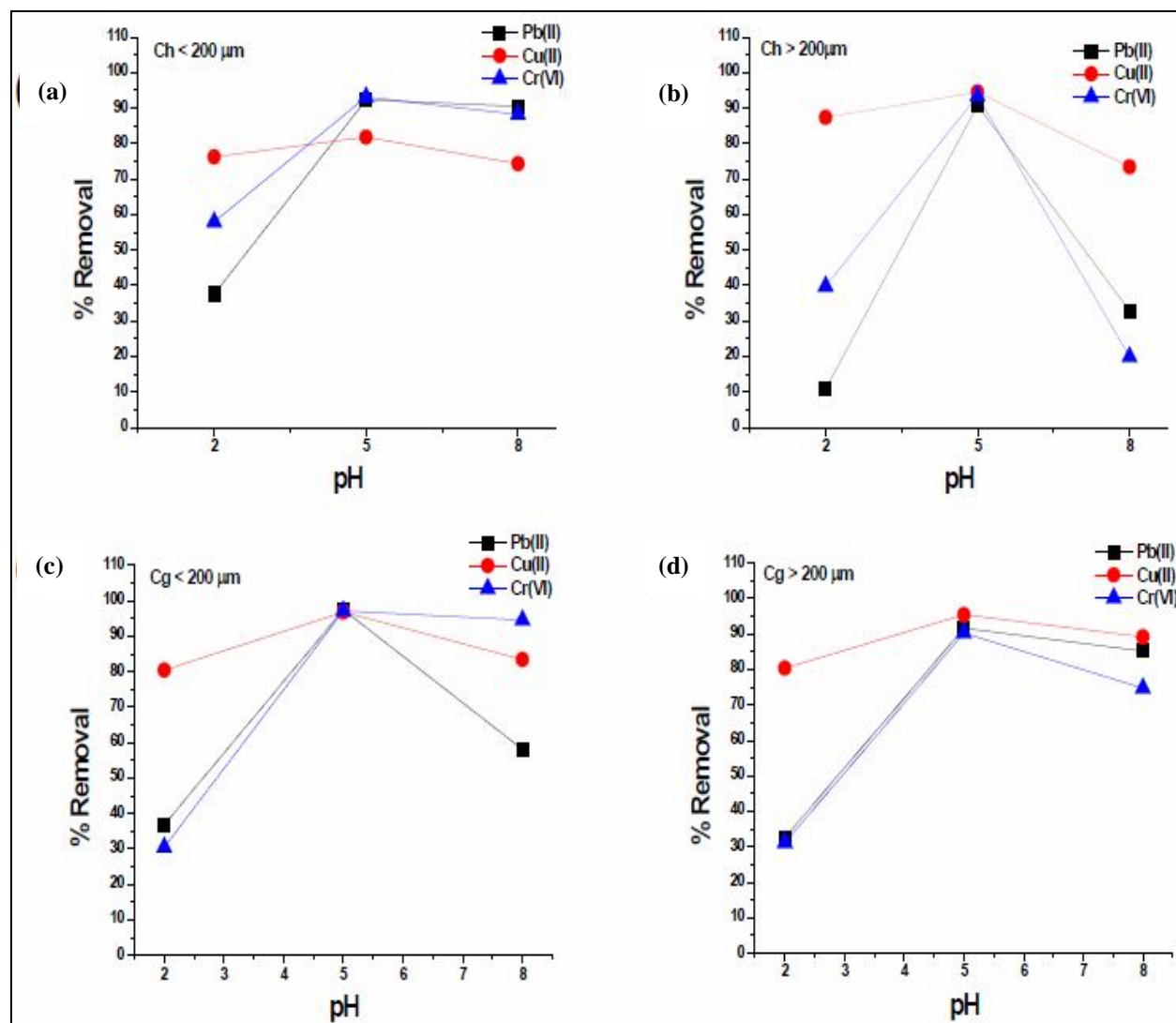

Figure 1. **Effects of pH on the adsorption of lead(II), copper(II) and chromium(VI) using coffee husk (Ch) and coffee ground (Cg) at a particle size (a) Ch < 200 µm, (b) Ch > 200 µm, (c) Cg <200 µm, (d) Cg > 200 µm**

Effect of Contact Time

The effect of contact time on the adsorption capacity of lead(II), copper(II), and chromium(VI) was illustrated in Fig. 2. It was shown that the adsorption capacity of a coffee husk to lead(II) increased from 73.4% to 83% for a particle size smaller than 200 µm and from 70% to 76.6% for the size of an adsorbent greater than 200 µm. On the other hand, lead(II) adsorption for coffee ground increased from 73.4% to 86.6% for particle size less than 200 µm and from 66.6% to 96% for particle size greater than 200 µm, when the contact time increased from 30 min to 60 min. However, above 60 min, the adsorption capacity was decreased. These results were in agreement with the study's findings [14].

Results of the effect of contact time on the adsorption of copper(II), which was illustrated in Fig. 2, showed that when the contact time increased from 30 min to 60 min, the adsorption efficiency of a coffee husk rose from 52% to 94.94% for particle size <200 µm and 31.8% to 93.28% for particle size >200 µm. On the other hand, the adsorption capacity of coffee ground for copper(II) increased from 19.6% to 97.3% for a Particle size, lower than 200 µm and 68.6% to 80% for coffee ground particle size, above 200 µm, but when the contact time above 60 min was decreased. The findings of this study were almost similar to the results of the research done by [2].
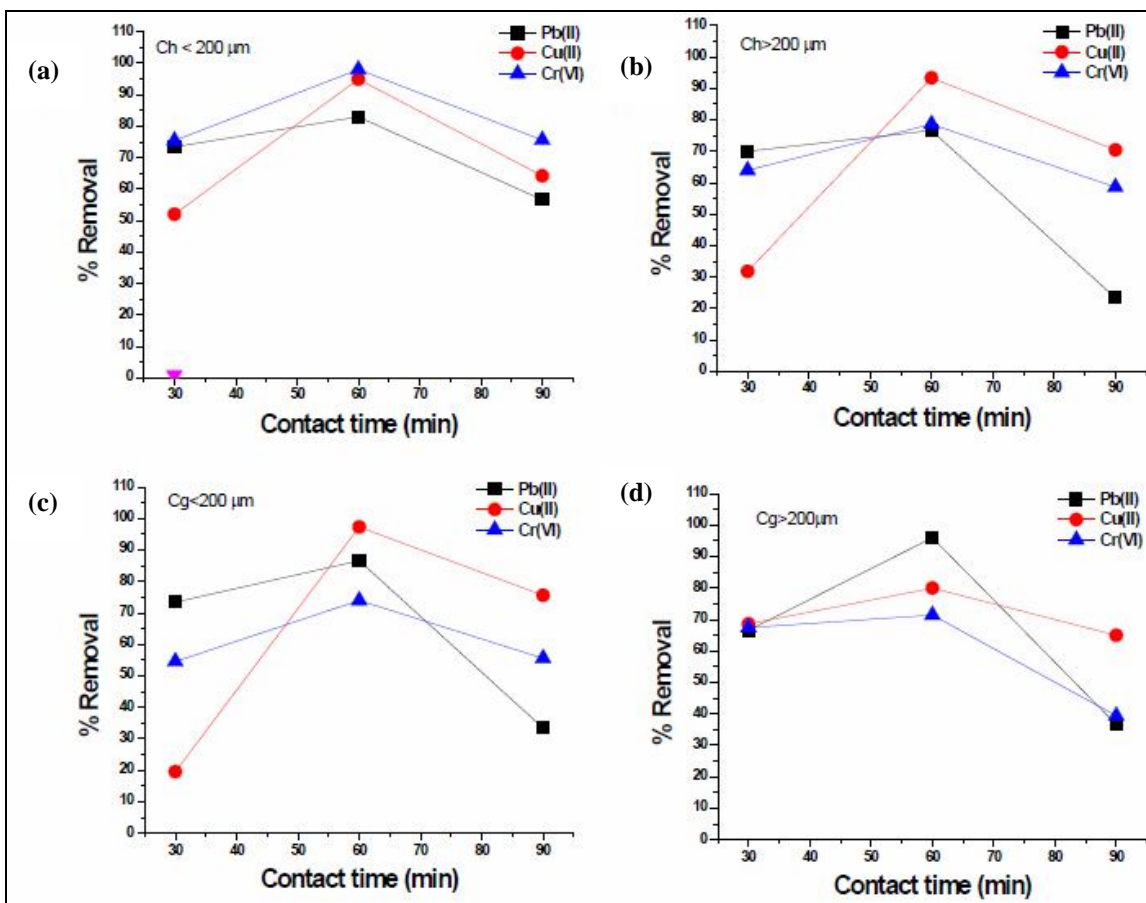

Figure 2. **Effects of contact time on the adsorption of lead(II), copper(II) and chromium(VI) using coffee husk (Ch) and coffee ground (Cg) at a particle size (a) Ch < 200 µm, (b) Ch > 200 µm, (c) Cg <200 µm, (d) Cg > 200 µm**

Results of the effect of contact time on the adsorption capacity of chromium(VI) in Fig. 2 showed that the adsorption efficiency of a coffee husk increased from 75.4% to 98% for particles, <200 µm and 64% to 78.6% for particle size >200 µm. On the other hand, the adsorption efficiency of a coffee ground increased from 54.6% to 74% for a Particle size <200 µm and 67.4% to 71.4% for a particle size >200 µm when the contact time increased from 30 min to 60 min. However, above 60 min, the adsorption potential was decreased. The result was in agreement with the findings by Teshome [25].

Generally, the rapid initial adsorption may be a manner of the accumulation of metals onto the surface of the adsorbent due to a large number of free-binding sites. With the progressive occupation of these sites, the process above 60 min became slower. It is in line with the observations of other similar studies [2, 14]. The removal efficiency turned sharply at a contact time of 60 min, and this optimum time was selected as the contact time for all experiments.

Effect of Initial Concentration

Metal adsorption was influenced by the initial concentration of metal ions in aqueous solutions. In the present study, the initial metal concentration was varied from 0.5 to 1.5 mg/L for each adsorbent fraction. Results of the study on the influence of initial concentration of lead(II), copper(II), and chromium(VI) on the removal capacity of the coffee husk and the coffee ground are presented in Fig. 3. It shows the effect of initial concentration on the removal percentage of the metal ion. The result illustrated in Fig. 3 showed that the adsorption efficiency of coffee husk increased initially and then decreased for a lead(II) from 94.2% at 0.5 mg/L to 86.63% at 1.5 mg/L coffee husk, for the particle size, <200 µm. For

coffee husk, particle size >200 µm, the removal efficiency of lead(II) decreased from 93.2% at 0.5 mg/L to 65% at 1.5 mg/L. On the other hand, a coffee ground increases initially and then decreases for lead(II) from 96.53% at 0.5 mg/L to 73.4% at 1.5 mg/L coffee ground, particle size <200 µm. The removal capacity of lead(II) from 96.06% at 0.5 mg/L to 88.5% at 1.5 mg/L coffee ground, particle size, >200 µm. Experimental results showed that coffee husk and coffee ground could be excellent natural adsorbents for lead(II) removal from aqueous solutions. This was supported by previous research findings [14].

Experimental investigations showed that coffee husk and coffee grounds could be excellent natural adsorbents for copper(II) removal from aqueous solutions. The result illustrated in Fig. 3 also showed that the adsorption efficiency of the coffee husk (particle size <200 µm) increases initially and then decreases for copper(II) from 97.6% at 0.5 mg/l to 88.08 % at 1.5 mg/L. For coffee husk, particle size >200 µm, the removal efficiency of copper decreased from 97.2 % at 0.5 mg/L to 80.33 % at 1.5 mg/L. On the other hand, the removal efficiency of coffee ground (particle size <200 µm) increases initially and then decreases for copper(II) from 97.6% at 0.5 mg/L to 89.23% at 1.5 mg/L. The removal capacity of copper(II) from 83% at 0.5 mg/l and 74.38% at 1.5 mg/L coffee ground, particle size >200 µm in the aqueous solution. Which is similar to the previous study result [2].

The result presented in Fig. 3 showed that the adsorption efficiency of coffee husk increased initially and then decreased for chromium(VI) from 93.5% at 0.5 mg/L to 79.6% at 1.5 mg/L Coffee husk of particle size <200 µm. For coffee husk, particle size >200 µm the removal efficiency of chromium declined from 92.4% at 0.5 mg/L to 79.6% at 1.5 mg/L. On the other hand, the removal potential of coffee ground increased initially

and then decreased for chromium from 95.66% at 0.5 mg/L to 83.71% at 1.5 mg/L Coffee ground of particle size lower than 200 µm. The removal capacity of chromium(VI) was decreased from 94.46% at 0.5 mg/L to 73.75% at 1.5 mg/L for a coffee ground of particle size >200 µm in the aqueous solution. Experimental findings have indicated that coffee husk and grounds can be excellent natural adsorbents for chromium removal from aqueous solutions. This study is in agreement with the previous study by Teshome [25].

Generally, the results showed that lower concentrations of lead(II), copper(II), and chromium(VI) ions are small relative to the available adsorption sites on the adsorbent. The available adsorption sites become fewer when the initial concentration decreases and the particle size of an adsorbent aqueous solution increases. Consequently, adsorption becomes independent of initial concentration, and as a result, the adsorption was found to increase at a higher concentration in most of the adsorption sites. Therefore, the percentage removal of lead, copper, and chromium ions depends on the lead(II), copper(II), and chromium(VI) ions' occupied. The findings of this study agree with the previous research findings [14].
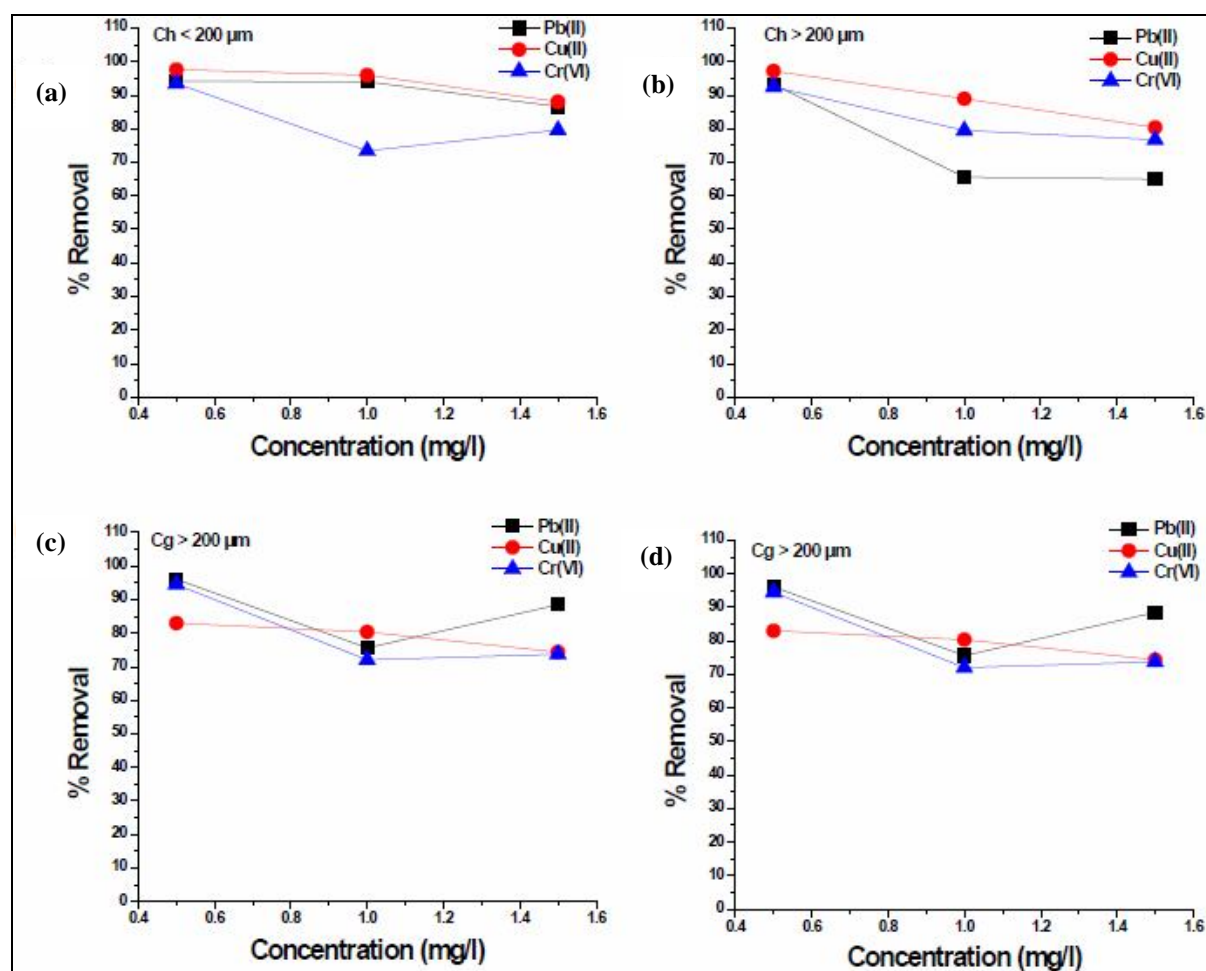

Figure 3. Effects of initial concentration on the adsorption of lead(II), copper(II) and chromium(VI) using coffee husk(Ch) and coffee ground (Cg) at a particle size (a) Ch < 200 µm, (b) Ch > 200 µm, (c) Cg <200 µm, (d) Cg > 200 µm.

Effect of Agitation Rate

The agitation speed effect on the adsorption of lead(II) illustrated in Fig 4 showed that the adsorption efficiency of coffee husk increased from 73.4% to 83% for a particle size lower than 200 μm and from 70% to 76.6% for a particle size above 200 μm. On the other hand, for a Coffee ground, the adsorption potential increased from 73.4% to 86.6% at a particle size, lower than 200 μm, and rose from 66.6% to 96% at a particle size above 200 μm when the agitation rate increased from 100 to 115 rpm. However, above 115 rpm, the removal efficiency was decreased, similar to the previous study [2].

The effect of agitation speed on the adsorption of copper(II) was illustrated in Fig 4. It was shown that the adsorption efficiency of coffee husk increased for copper(II) from 52% to 94.94% at a particle size of adsorbent <200 μm and for the adsorbent particle size >200 μm, the amount removed was increased from 31.8% to 93.28%. On the other hand, coffee ground removal potential increased for copper from 19.6% to 97.3% at a particle size <200 μm and from 68.6% to 80% at a particle size >200 μm when the agitation rate increased from 100 to 115 rpm. However, above 115 rpm, the removal efficiency of the adsorbent was decreased. This finding is similar to the previous study reported [2].
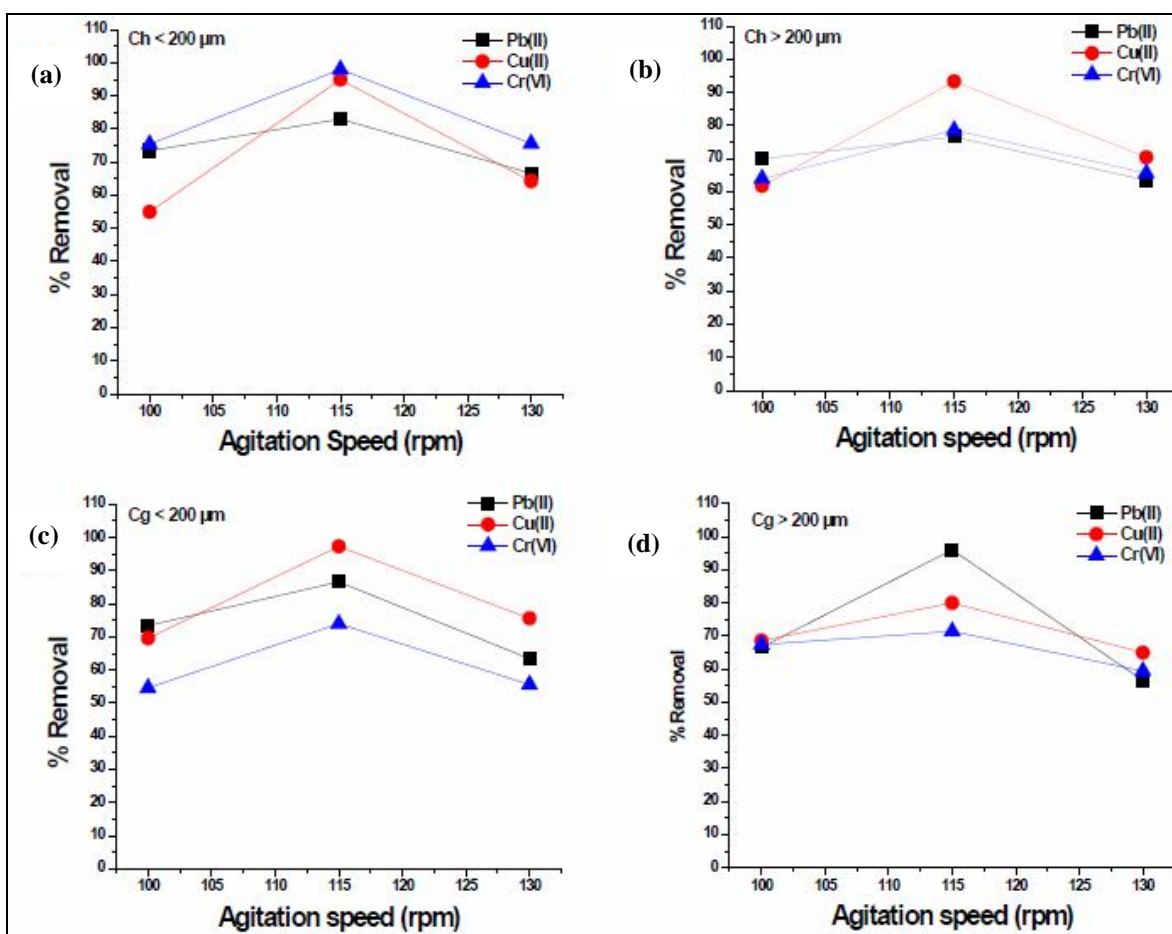

Figure 4. **Effects of agitation speed on the adsorption of lead(II), copper(II) and chromium(VI) using coffee husk(Ch) and coffee ground (Cg) at a particle size (a) Ch < 200 μm, (b) Ch > 200 μm, (c) Cg <200 μm, (d) Cg > 200 μm**

The effect of agitation speed on the adsorption of chromium(VI) is illustrated in Fig 4. The results showed that the adsorption efficiency of coffee husk increased for chromium from 75.4% to 98% at a particle of adsorbent lower than 200 µm and 64% to 78.6% at a particle size above 200 µm. In contrast, the efficiency of the coffee ground increased for chromium from 54.6% to 74% at a particle size <200 µm and 67.4% to 71.4% at a particle size >200 µm when the agitation rate increased from 100 to 115 rpm. But, above 115 rpm, the removal potential was decreased. This study agrees with the previous research [2].

In general, an increase in agitation rate improves the diffusion of metal ions toward the adsorbent surface, and the same thing was observed in this study. Therefore, the decreased value of the lead(II), copper(II), and chromium(VI) adsorbed by coffee husk and coffee ground after 115 rpm was the result of an extreme agitation rate that causes more metal ions to be desorbed from the adsorption sites [14].

Conclusion

In this study, the effects of different parameters such as adsorbate concentration, adsorbent (coffee husk and coffee ground) dose, agitation speed, contact time, and pH on the adsorption efficiency of coffee husk and coffee ground were studied by varying the parameters. The findings showed that the coffee husk and coffee ground were better adsorbents for removing heavy metals from aqueous solutions. The results also revealed that a higher degree of heavy metal adsorption was achieved at a pH of 5, contact time of 60 min, an agitation speed of 115 rpm, an adsorbent dosage of 0.5 g, and an initial concentration of 0.5 mg/L.

Availability of data and materials

Data generated during this research work can be available upon request.

Conflict of Interests

The authors declare that they have no competing interests.

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