Separation Science and Technology

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713708471

Removal of Copper, Lead, and Cadmium Ions in a Fluidized Bed

Hasan Mousa[a]; Munther Kandah[a]; Fahmi A. Abu Al-Rub[b]
[a] Department of Chemical Engineering, Jordan University of Science and Technology, Irbid, Jordan [b] Chemical and Petroleum Engineering Department, United Arab Emirates University, Al-Ain, United Arab Emirates

To cite this Article Mousa, Hasan , Kandah, Munther and Al-Rub, Fahmi A. Abu(2005) 'Removal of Copper, Lead, and Cadmium Ions in a Fluidized Bed', Separation Science and Technology, 39: 8, 1751 — 1760
To link to this Article: DOI: 10.1081/SS-120035936
URL: http://dx.doi.org/10.1081/SS-120035936

SEPARATION SCIENCE AND TECHNOLOGY
Vol. 39, No. 8, pp. 1751–1760, 2004

Removal of Copper, Lead, and Cadmium Ions in a Fluidized Bed

**Hasan Mousa,[1],* Munther Kandah,[1] and
Fahmi A. Abu Al-Rub[2]**

[1]Department of Chemical Engineering, Jordan University of Science
and Technology, Irbid, Jordan
[2]Chemical and Petroleum Engineering Department, United Arab
Emirates University, Al-Ain, United Arab Emirates

ABSTRACT

In this study, the recovery of copper from synthetic wastewaters prepared from $CuSO_4$ was studied using a fluidized bed containing hydrogen-based solid Amberlite. The effects of operating parameters including liquid flow rate, initial copper ions concentration, pH of the influent solution, and Amberlite weight on the breakthrough curves were investigated. It was found that the copper uptake increased with the increase in Amberlite weight, the decrease in initial copper concentration, and decrease in liquid flow rate, but there was no affect with solution influent pH. The recovery of cadmium and lead ions prepared from $CdSO_4$ and $Pb(NO_3)_2$, respectively, was also investigated. Comparison between the adsorption of

---

*Correspondence: Hasan Mousa, Department of Chemical Engineering, Jordan University of Science and Technology, P.O. Box 3030, Irbid 22110, Jordan; E-mail: akras@just.edu.jo.

DOI: 10.1081/SS-120035936 0149-6395 (Print); 1520-5754 (Online)

www.dekker.com

Cu^{2+}, Cd^{2+} and Pb^{2+} showed that the adsorption capacity followed the following order: $Pb^{2+} > Cd^{2+} > Cu^{2+}$. It was found that the order of adsorption was independent of the flow rate or the initial feed concentration.

Key Words: Adsorption; Fluidization; Waste water; Industrial waste; Heavy metals.

INTRODUCTION

Contamination of surface waters due to wastewater discharge containing heavy metals is becoming a universal problem. The presence of heavy metals at even very low concentration can cause many ecological and health problems. Copper, cadmium, and lead are examples of these toxic heavy metals. In humans, copper can cause serious problems, such as stomach intestinal distress, kidney damage, and anemia. Studies on humans and experimental animals showed that cadmium has a potential for carcinogenic effects.[1]

Different treatment methods have been used and developed for the removal of these heavy metals from aqueous solutions. These methods include chemical precipitation, reverse osmosis, ion exchange, electrodialysis, and adsorption. Adsorption is a well-known equilibrium separation process that has been proven to be effective for heavy metals removal. Abu Al-Rub et al.[2,3] have proven the suitability of using adsorption on sheep manure wastes to remove nickel and cadmium Kandah et al.[4] used the sheep manure wastes for the simultaneous removal of nickel–copper and nickel–cadmium from wastewaters. Tee and Khan[5] investigated the removal of heavy metals, such as lead, cadmium, and zinc, from wastewater using waste tea leaves. Ferro-Garcia et al.[6] studied the removal of heavy metals by adsorption on activated carbons obtained from agricultural by-products, such as almond shells, olive stones, and peach stones. Tobin et al.[7] studied the use of *Rhizopus arrhizus* biomass in the removal of heavy metals from wastewater. Reed et al.[8] investigated the removal of cadmium ions from aqueous solutions by adsorption on granular activated carbon. Ho and McKay[9] studied the removal of lead ions by adsorption on peat.

Ion exchange is another common method used for heavy metal removal. Loureiro et al.[10] used the chelating resin Doulite ES 346 for the recovery of individual heavy metals, such as copper, zinc, and lead, from a solution using a packed bed. However, packed beds have some disadvantages, such as high pressure drop and clogging of the beds,[11] that may limit their use. Alternatively, ion exchange fluidized beds (IEFBs) do not have such limitations. Hwang et al.[11] used a fluidized bed ion exchange for the removal of copper and nickel ions from wastewater.

This study aimed at investigating the removal of three individual heavy metals, namely, copper, cadmium, and lead, by IEFB. The effects of different physical and chemical parameters, such as metal concentration, flow rate, and pH, on the performance of the IEFB was studied.

EXPERIMENTAL PART

The fluidized bed used in this study was a cylinder made of Plexiglas of 1.5 m in length and 0.08 m inner diameter. A liquid distributor was placed at the bottom where a mesh of 0.1 mm in diameter was fixed over it to arrest the flow of fine particles. Glass beads were packed between the mesh and the distributor. At the top of the fluidized bed, a retaining grid was also fixed. Eight holes, 0.15 m apart, were made between the mesh and the retaining grid. A rubber cork, through which a needle could be inserted to withdraw liquid samples for analysis purposes, closed the holes. The reasons for making eight holes was to allow taking more than one sample at the same time and to allow withdrawing samples from the section above the expanded bed (Fig.1).

Adsorption studies on hydrogen-based Amberlite (1R 120 LR S. D. Fine Chem. Ltd.) were carried out using stock water solutions of various concentrations of Cu^{2+}, Pb^{2+}, or Cd^{2+} ranging from 50 to 170 ppm. The Amberlite had a density of $1300\,kg/m^3$. Its average-particle diameter was 5×10^{-4} m and its adsorption capacity for $Cu^{2+}$was 3.64×10^{-5} kg Cu^{2+}/kg Amberlite. Adsorption isotherms of such Amberlite were studied elsewhere.[11] The feed

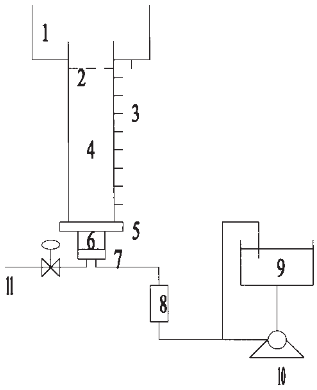

Figure 1. Schematic diagram of the apparatus used. (1) Overflow reservoir; (2) retaining grid; (3) sampling ports; (4) fluidized bed; (5) mesh; (6) glass bead; (7) liquid distributor; (8) rotameter; (9) feed tank; (10) pump; (11) drain.

solutions were prepared from $CuSO_4$, $Pb(NO_3)_2$, and $CdSO_4$, respectively. The effect of the flow rate was studied by carrying out the experiments at different flow rates ranging from 4 to 9 L/min. These flow rates correspond to 2–4.5 times the minimum fluidization flow rate (2 L/min). The concentration of the ions in the feed and the effluent streams was measured by taking samples and analyzing them using an atomic absorption spectrophotometer. Some of the experiments were duplicated to confirm the reproducibility of the experimental results.

The effect of the amount of the adsorbent was studied by charging the bed with 100, 150, and 200 g of Amberlite. These amounts of Amberlite occupy 1.3%, 1.9%, and 2.6% of the total bed volume, respectively. The effect of pH was also studied by performing experiments at pH values ranging from 2 to 6. All of the experiments were performed at room temperature.

RESULTS AND DISCUSSION

Figure 2 shows the effect of the initial $CuSO_4$ on the efficiency of Cu^{2+} adsorption on Amberlite surface at a feed flow rate of 4 L/min,

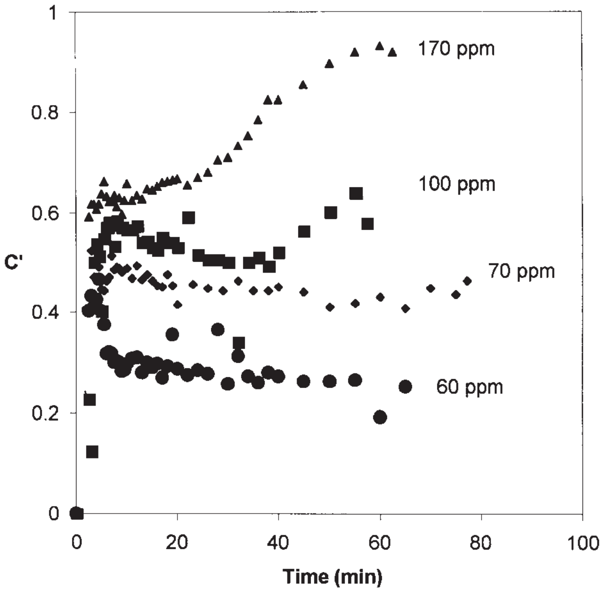

Figure 2. Dimensionless concentration of Cu^{2+} vs. time for various feed concentration. The feed flow rate is 4 L/min, pH = 5.78, and the weight of Amberlite is 100 g.

pH = 5.78, and the weight of Amberlite is 100 g. As can be seen from the figure, the Cu^{2+} concentration in the effluent stream was larger as the initial Cu^{2+} concentration was raised. It is obvious that due to the availability of Cu^{2+}, the surface of the Amberlite reached saturation and no more Cu^{2+} could be adsorbed, leading to higher Cu^{2+} in the effluent stream.

The effect of the feed flow rate on the efficiency of Cu^{2+} adsorption for feed concentration of 170 ppm, pH of 5.78, and bed weight of 100 g Amberlie is depicted in Fig. 3. It can be seen from Fig. 3 that as the flow rate increased, the concentration of Cu^{2+} in the effluent stream was higher. One would expect that more Cu^{2+} would be adsorbed as the flow rate increases since the diffusion rate is usually proportional to the flow rate. Moreover as the flow rate increases the bed expands, giving more time for the liquid in the bed, L_{bed}/v. The above two points result in lower Cu^{+2} concentration in the effluent stream. However, as the flow rate increases, the copper ions are not given enough time to diffuse toward the resin surface, leading to higher Cu^{2+} concentration in the effluent stream A competition between the facts exists, leading to the trend exhibited in Fig. 3. The trend can be also explained from another point of view, as follows. As the flow rate increases, more Cu^{2+} is fed to the bed. This is equivalent to increasing the feed concentration,

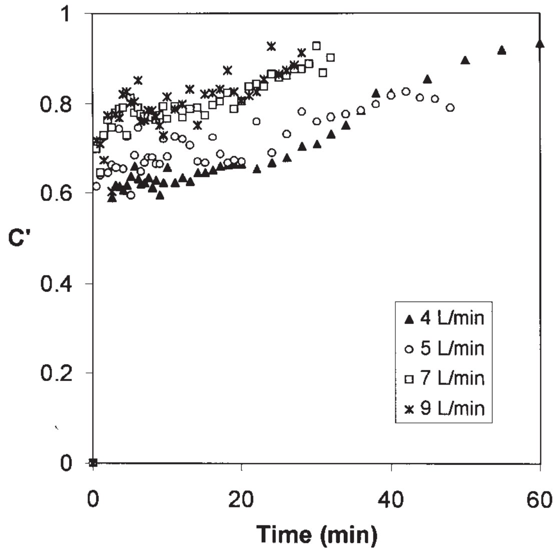

Figure 3. Dimensionless concentration of Cu^{2+} vs. time for various feed flow rates. The feed concentration is 170 ppm, pH = 5.78, and the bed contains 100 g of Amberlite.

which leads to higher Cu^{2+} concentration in the effluent stream, similar to the results shown in Fig. 2. It should be mentioned that Hwang et al.[11] found that as the flow rate increases, the concentration of Cu^{2+} was lower. A result opposite to the one found in this study. They explained the results by the fact that the residence time is larger due to bed expansion, only without mentioning the other two factors.

The effect of the amount of resin charged to the bed at a flow rate of 4 L/min, pH of 5.78, and feed concentration of 170 ppm Cu^{2+} is portrayed in Fig. 4. As expected, the larger the amount of resin (indicating the higher the surface area available for adsorption), the more the Cu^{2+} was adsorbed. This results in a lower Cu^{2+} concentration in the effluent stream, which agrees with the results obtained by Hwang et al.[11]

The effect of the pH of the feed on the adsorption at a flow rate of 4 L/min, Amberlite weight of 100 g, and feed concentration of 170 ppm Cu^{2+} is shown in Fig. 5. As can be seen from the figure, the initial pH has no influence on the rate of adsorption. This is due to the fact that the pH of the liquid phase in the fluidized bed is determined mainly by the amount of H^+ released from the resins, and this pH is constant for various values of the pH of the inlet solution used in experiments. Therefore, the breakthrough curve of Cu^{2+} was not affected by the pH of the influent solution.

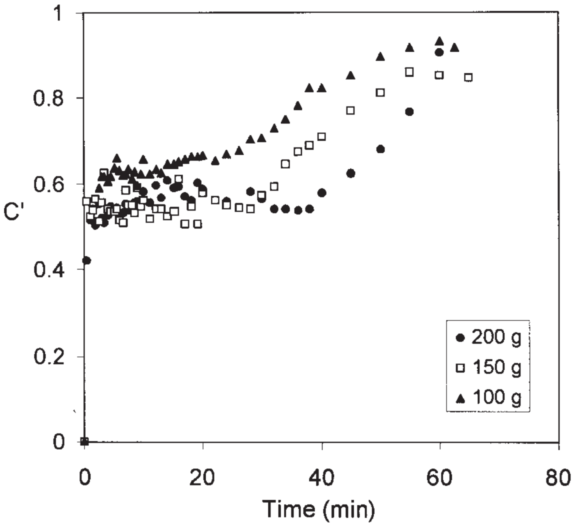

Figure 4. Dimensionless concentration of Cu^{2+} vs. time for various Amberlite weights. The feed flow rate is 4 L/min, feed concentration = 170 ppm, and pH = 5.78.

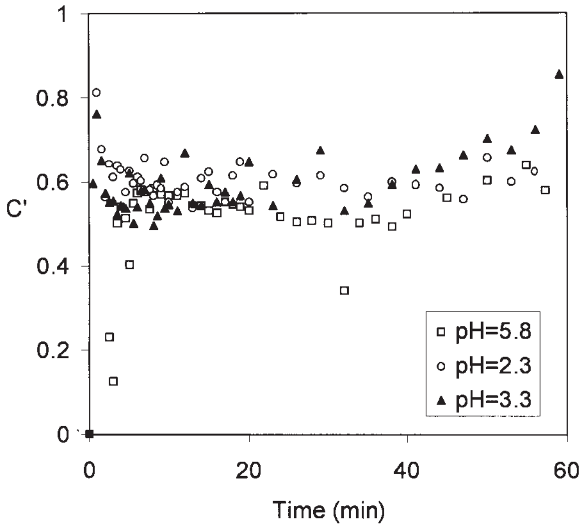

Figure 5. Dimensionless concentration of Cu^{2+} vs. time for various pH value of the feed. Feed flow rate = 4 L/min, concentration = 170 ppm, and weight of Amberlite = 100 g.

Adsorption of Cd^{2+} and Pb^{2+} at an initial concentration of 100 ppm, a flow rate of 4 L/min, pH of 5.78, and Amberlite weight of 100 g for each case was also performed. A comparison between the adsorption of the three ions (Cu^{2+}, Cd^{2+}, and Pb^{2+}) is shown in Fig. 6. It can be noticed that the adsorption rate of the ions follows the following order $Pb^{2+} > Cd^{2+} > Cu^{2+}$. This indicates that the adsorption rate is directly proportional to the size of the ion, implying that the adsorption process was not diffusion controlled. The same result was obtained when the experiments were repeated at an initial concentration of 150 ppm, a flow rate of 4 L/min and weight of Amberlite of 100 g, as shown in Fig. 7. To further fortify this point, the experiments were repeated at 100 ppm, weight of Amberlite of 100 g, pH of 5.78, and a flow rate of 8 L/min, as shown in Fig. 8. It can be seen that the order of adsorption was still the same.

CONCLUSION

From the results obtained in this research, the following can be concluded. Heavy metals, such as Cu^{2+}, Cd^{2+}, and Pb^{2+}, can be removed from

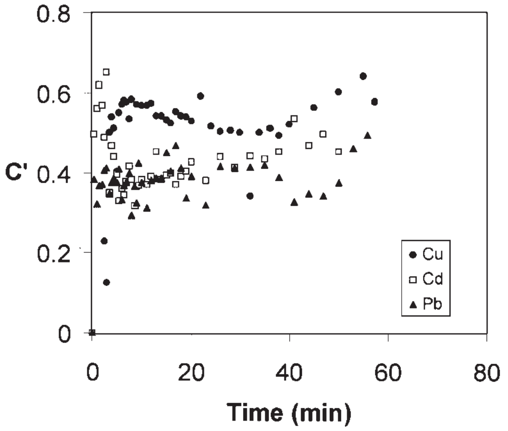

Figure 6. Dimensionless concentration of Cu^{2+}, Cd^{2+}, and Pb^{2+} vs. time at a flow rate of 4 L/min and initial concentration of each ion of 100 ppm. The pH = 5.78 and the weight of Amberlite = 100 g.

wastewater in a fluidized bed. The adsorption rate is proportional to the amount of resin. The pH value has no influence on the adsorption of Cu^{2+} to Amberlite. In the range of flow rate studied, adsorption of Cu^{2+} ions was inversely proportional to the flow rate. The adsorption of the ions studied in this research followed the following order: $Pb^{2+} > Cd^{2+} > Cu^{2+}$. Under

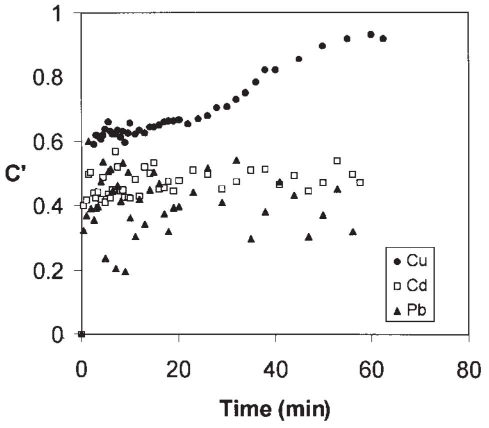

Figure 7. Dimensionless concentration of Cu^{2+}, Cd^{2+}, and Pb^{2+} vs. time at a flow rate of 4 L/min and initial concentration of each ion of 150 ppm. The pH = 5.78 and weight of Amberlite = 100 g.

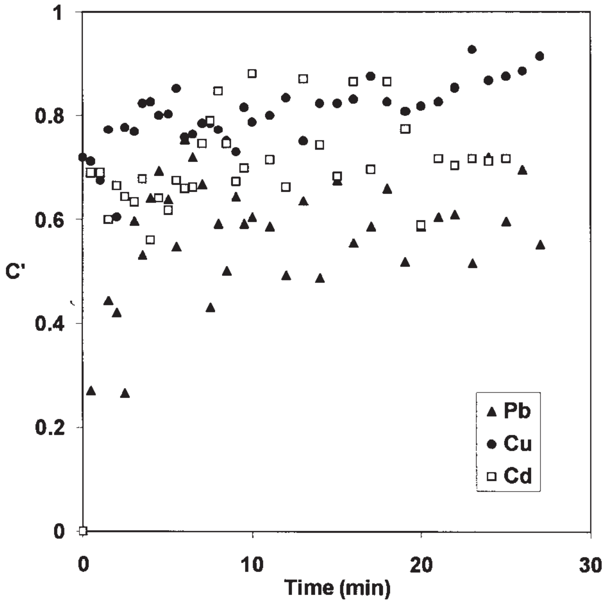

Figure 8. Dimensionless concentration of Cu^{2+}, Cd^{2+}, and Pb^{2+} vs. time at a flow rate of 8 L/min and initial concentration of each ion of 100 ppm. The pH = 5.78 and weight of Amberlite = 100 g.

the experimental conditions studied in this research, the adsorption process was not diffusion controlled.

NOMENCLATURE

C'	dimensionless concentration = $C(t)/C_0$
C_0	initial concentration, ppm
L_{bed}	bed length, m
v	fluidization velocity, m/s

REFERENCES

1. Karabulut, S.; Karabaka, A.; Denizli, A.; Yurum, Y. Cadmium (II) and mercury (II) removal from aquatic solutions with low-rank Turkish coal. Sep. Sci. Technol. **2002**, *36*, 3657.

2. Abu Al-Rub, F.; Kandah, M.; Al-Dabaybeh, N. Nickel removal from aqueous solutions using sheep manure wastes. Eng. Life Sci. **2002**, *2*, 111.
3. Abu Al-Rub, F.A.; Kandah, M.; Al-Dabaybeh, N. Competitive adsorption of nickel and cadmium on sheep manure wastes: experimental and prediction studies. Sep. Sci. Technol. **2003**, *38*, 463.
4. Kandah, M.; Abu Al-Rub, F.A.; Al-Dabaybeh, N. Competitive adsorption of copper–nickel and copper–cadmium binaries sheep manure wastes: experimental and prediction studies. Eng. Life Sci. **2002**, *8*, 237.
5. Tee, T.W.; Khan, R.M. Removal of lead, cadmium, and zinc by waste tea leaves. Environ. Tech. Lett. **1988**, *9*, 1223.
6. Ferro-Garacia, M.A.; Rivera-Utrilla, J.; Rodriguez-Gordillo, J.; Bautista-Toledo, I. Adsorption of zinc, cadmium, and copper on activated carbons obtained from agricultural by products. Carbon **1988**, *26*, 363.
7. Tobin, J.M.; Cooper, D.G.; Neufeld, R.J. Investigation of mechanism of metal uptake by denatured *Rhizopus arrhizus* biomass. Enzyme Microb. Technol. **1990**, *12*, 591.
8. Reed, B.E.; Arunachalam, S.; Thomas, B. Removal of cadmium from aqueous waste streams using granular activated carbon columns. Environ. Prog. **1994**, *13*, 60.
9. Ho, Y.S.; McKay, G. The sorption of lead(II) ions on peat. Wat. Res. **1999**, *33*, 578.
10. Loureior, J.M.; Costa, C.A.; Rodrigues, A.E. Recovery of copper, zinc and lead from liquid stream by chelating ion exchange resins. Chem. Eng. Sci. **1988**, *43*, 1115.
11. Hwang, S-J.; Lo, Y-C.; Lu, W-J. Multicomponent ion exchange in a fluidized bed. J. Chin. I. Che. E. **1996**, *27*, 9.

Received April 2003

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

Downloaded At: 10:06 25 January 2011

Request Permission or Order Reprints Instantly!

Interested in copying and sharing this article? In most cases, U.S. Copyright Law requires that you get permission from the article's rightsholder before using copyrighted content.

All information and materials found in this article, including but not limited to text, trademarks, patents, logos, graphics and images (the "Materials"), are the copyrighted works and other forms of intellectual property of Marcel Dekker, Inc., or its licensors. All rights not expressly granted are reserved.

Get permission to lawfully reproduce and distribute the Materials or order reprints quickly and painlessly. Simply click on the "Request Permission/ Order Reprints" link below and follow the instructions. Visit the U.S. Copyright Office for information on Fair Use limitations of U.S. copyright law. Please refer to The Association of American Publishers' (AAP) website for guidelines on Fair Use in the Classroom.

The Materials are for your personal use only and cannot be reformatted, reposted, resold or distributed by electronic means or otherwise without permission from Marcel Dekker, Inc. Marcel Dekker, Inc. grants you the limited right to display the Materials only on your personal computer or personal wireless device, and to copy and download single copies of such Materials provided that any copyright, trademark or other notice appearing on such Materials is also retained by, displayed, copied or downloaded as part of the Materials and is not removed or obscured, and provided you do not edit, modify, alter or enhance the Materials. Please refer to our Website User Agreement for more details.

Request Permission/Order Reprints

Reprints of this article can also be ordered at

http://www.dekker.com/servlet/product/DOI/101081SS120035936