

Batch Adsorption Studies of Natural Composite Hydrogel for Removal of Co(II) Ions

A. Marey & Doaa F. Ahmed

Department of Basic Science, The Valley Higher Institute for Engineering and Technology, El- Obour 11828, Egypt

Submitted: 6/5/2022. Revised edition: 5/9/2022. Accepted: 6/9/2022. Available online: 20/11/2022

ABSTRACT

Innovative methods for handling industrial wastewater containing heavy metals has been receiving significant attention from researchers in recent years. Proper treatment of wastewater is compulsory to avoid the release of toxic heavy metal ions into water bodies. In this study, we developed a new adsorptive material, i.e., orange peel/acrylamide composite hydrogel for the removal of Co(II) ions from aqueous solution. The results showed that the adsorption of Co(II) by our hydrogen was well-fitted with the pseudo-second-order model. Its adsorption rate against Co(II) ions could reach up to 56 mg/g at pH 6. Further investigations are still needed to maximize the adsorption capacity of orange peel/acrylamide composite hydrogel.

Keywords: Hydrogel, orange peel, adsorbent materials, metal removal, wastewater

1.0 INTRODUCTION

As a material, hydrogel is extremely adaptable and may be used to a wide range of uses. Toxic or radioactive elements may be removed from a wide range of effluents using this material as an adsorbent, and metal pre-concentration can be used to examine environmental samples made from aqueous solutions. As a type of polymeric materials, the hydrogels can store enormous quantities of water in three-dimensional networks due to their hydrophilic structure [1]. It is critical that these products are widely used in a variety of industrial and environmental contexts. It is anticipated that synthetic hydrogels will be phased out over time because to their lower water absorption capacity, longer service life, and wider variety of basic chemical resources.

Scientific fields, in particular, are

doing an increasing amount of research on this subject. Since heavy metals tend to accumulate in living organisms and many are harmful or carcinogenic, the EPA lists them as priority pollutants [2]. The lungs, kidneys, central nervous system, nose, skin, and gastrointestinal tract are all affected by heavy metal ions pollution [3, 4, 5]. However, heavy metals continue to have an impact on the environment today. The situation has worsened in certain parts of the globe. Contamination of water resources due to the dumping of heavy metals has become a significant global problem in recent decades. Toxic or hazardous metals like chromium and antimony include copper, lead and mercury [6], as well as cadmium and manganese.

The objective of this work is to develop a new adsorptive material, i.e., orange peel/acrylamide composite hydrogel for potential use in Co(II) ion

* Corresponding to: A. Marey (email: ameraraafat9@gmail.com)

DOI: <https://doi.org/10.11113/amst.v26n3.244>

removal. The effects of key parameters such as ion concentration and contact time on the performance of orange peel/acrylamide composite hydrogel are studied.

2.0 EXPERIMENTAL SETUP

2.1 Materials Preparation and Characterization

In the winter, orange peel was collected from the surrounding area in Egypt. Acryl amide (AAM) was purchased from win lab of purity (99%) and M.wt 71.08 a.m.u (UK). Hydrochloric acid and/or sodium hydroxide solutions were used to modify the pH as needed throughout the experiment. $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ is a product of Sigma Aldrich's. Almost all of the materials, including chemicals and reagents, have been used without being cleaned in any way. (OP) (Orange peel) cleaned and rinsed with distilled water to eliminate any remaining material. When dry, the newly cleaned (OP) was crushed and sieved until the required particle sizes were achieved. Ismailia Canal (Mostorod refinery site) provided the wastewater as effluent used in this investigation: The turbidity (TSS) is (100.7) NTU, the pH is (8.32), and the temperature is (24.04°C) [7, 8, 9].

2.2 Preparation of Orange Peel-based Hydrogel

To make a homogeneous mixture with a 10% concentration, 100 ml distilled water was mixed with 10 g of (OP), swirled, and heated at 80°C for 120 minutes. (OP: AAM) [(1:1) (1:2), and (2:1)] monomers were continuously agitated at room temperature for 5 minutes as indicated in Figure 1. The solution was then cooled to room temperature and various quantities of

AAM were added. After being placed in a glass tube, the solution was exposed to the Co_{60} gamma radiation source at a range of dosage rates (10-50 kGy) as well as a constant dose rate of 1.46 kGy/h. In order to eliminate any remaining unreacted chemicals, the irradiated crosslinked (AAM/OP) hydrogel was washed in excess water before being air dried at room temperature.

2.3 Radiation Preparation of (AAM/OP) Hydrogel Composite

(AAM/OP) composite hydrogel was made by combining 0.1 g of orange peel with an equivalent amount of AAM monomer solution and stirring for 5 minutes. At room temperature, the viscous solution was placed into a glass tube and irradiated with Co_{60} gamma source, the vials were cracked and cut into discs with a thickness of 2 mm and a diameter of 5 mm, after the polymerization was completed [10]. the composite gel was rinsed with distilled water to remove any unreacted components before room temperature air drying. Figure 1 shows the procedure of forming AAm-OP hydrogel.

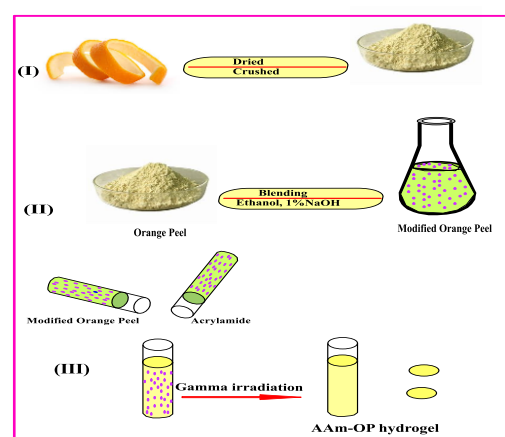


Figure 1 Formation of (Acrylamide – Orange peel) AAm-OP hydrogel

3.0 RESULTS AND DISCUSSION

3.1 Influence of Initial Metal Ions Concentration

Figure 2 shows the initial Co(II) concentration on the hydrogel's adsorption surface (AAM/OP). (AAM/OP) adsorbents removed a considerable percentage of cobalt ions

at lower concentrations, with cobalt ion absorption by unit mass of the adsorbent being almost same in both cases. As the concentration of metal ions in the solution rises, so does the initial concentration of metal ions in the aqueous solution [11]. The percentage of Cobalt (II) absorption decreases fast as the initial concentration increases.

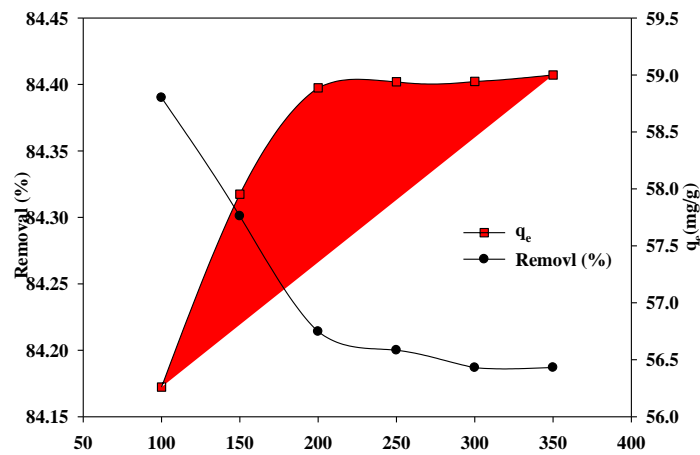


Figure 2 Influence of premier feed concentration of Cobalt ions on the adsorption of hydrogel at pH 6, contact time 48 h and at ambient temperature.

3.2 Adsorption Isotherm

Figure 3 shows linear isotherm plots of the Langmuir and the Freundlich model for adsorption of Co(II) onto the (AAM/OP) hydrogel, respectively, and the obtained data are summarized in

Table 1. According to the correction coefficients of both isotherm models, Co(II) adsorption fit The Freundlich isotherm model is superior to the Langmuir isotherm model in terms of accuracy.

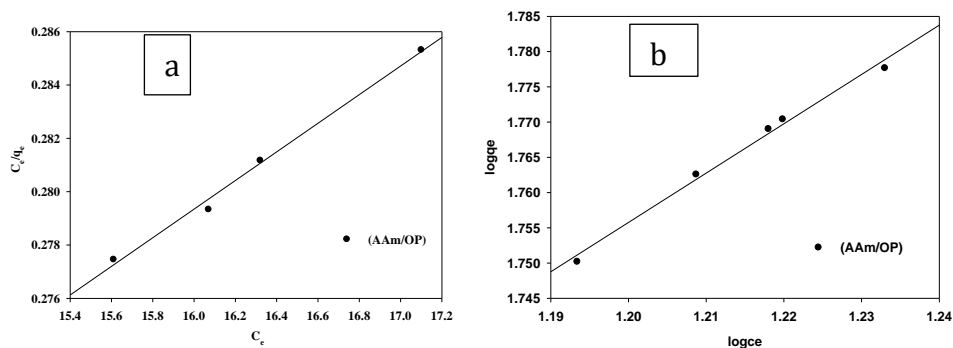


Figure 3 Adsorption of Cobalt ions onto a produced hydrogel using the (a) Langmuir adsorption isotherm and b) the Freundlich adsorption isotherm

Table 1 Model parameters for adsorption of Cobalt ions onto the produced hydrogel using the Langmuir and Freundlich isotherms

Langmuir model		Freundlich model	
Parameters	(AAM/OP)	Parameters	(AAM/OP)
q_m (mg/g)	186	K_F [mg/g(mg/L) (-1/n)]	8.2
k_a (L/mg) $\times 10^{-3}$	3.3	$1/n$	0.700
R_L	0.074	n	1.42
R^2	0.992	R^2	0.998

3.3 Influence of Contact Time

The significance of contact duration between (AAM/OP) hydrogel and Co(II) aqueous solution at pH = 6. Figure 4 shows the results of a study with an initial feed concentration of 100 mg/L [12]. The elimination percent of Co(II) ions increases fast

with contact time up to 20 minutes, when equilibrium is reached for the examined hydrogel. The concept that the Co(II) ions adsorption on the hydrogel is mostly due to electrostatic interactions is supported by the low contact time required to attain equilibrium [13, 14].

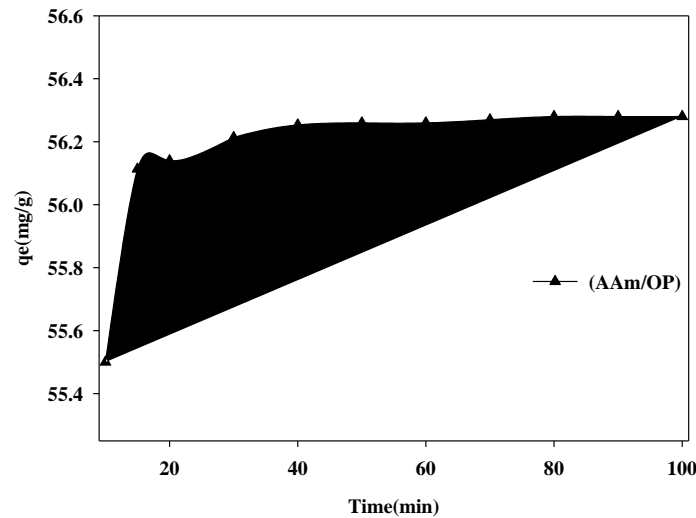


Figure 4 Impact of contact time on the adsorption capacity of hydrogel for Cobalt ions at pH 6, initial concentration 100 mg/l and at ambient temperature

3.4 Kinetics of Adsorption

This research made use of pseudo-first and pseudo-second order kinetic models. coating the hydrogel with cobalt ions, as seen in Figure 5: chemical pathways (a, b). Adsorption

of Co(II) onto an AAM/OP hydrogel may be described by a pseudo-second-order mechanism, as shown in Table 2, suggesting that the adsorption rate is controlled chemically. This is consistent with previous findings.

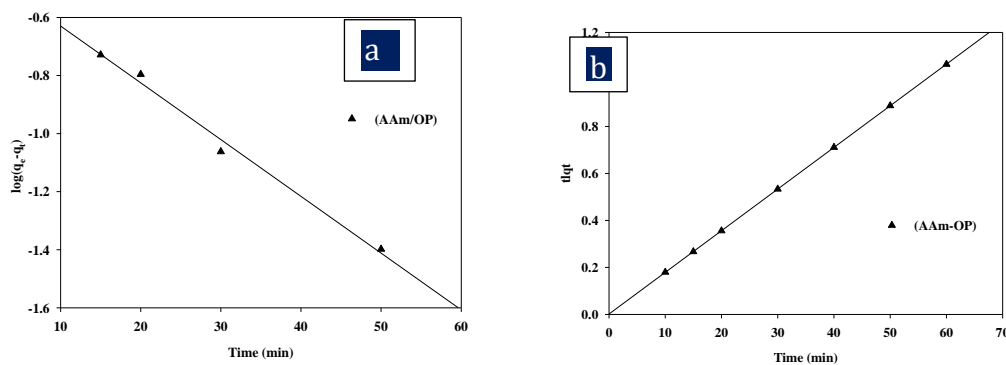


Figure 5 The kinetic plots of Cobalt ions adsorption onto hydrogel via (a) Pseudo-first-order model and (b) Pseudo-second-order model

Table 2 Model parameters for adsorption of cobalt ion onto a prepared hydrogel, first and second orders

Pseudo-first order		Pseudo-second order	
Parameters	(AAM/OP)	Parameters	(AAM/OP)
q_{ex}	56.30	k_2 (g/ mg min)	0.183
k_1 (min^{-1})	0.0499	q_e , cal (m g/ g)	56.4
q_e , cal (mg/ g)	0.37	R^2	0.999
R^2	0.9845		

4.0 CONCLUSION

Under various experimental circumstances, the elimination of Co(II) ions from wastewater using the created hydrogel was investigated utilizing Langmuir and Freundlich models for adsorption of Cobalt ions onto the researched hydrogel. The Freundlich isotherm model match the experimental data accurate. The rate of adsorption reduced as contact duration increased and a saturation stage was reached due to ions accumulation at the adsorption sites. This drop is owing to a reduction in the overall surface area of the adsorbent and an elevation in the diffusion. The adsorption of Co(II) was discovered to be appropriate well with the pseudo-second-order model.

REFERENCES

- [1] Ahmed, E. M. 2015. Hydrogel: Preparation, Characterization, and Applications. *J. Adv. Res.* 6: 105.
- [2] Aguayo, I. A., Montoya, H. P., López, R. and Montes, M. A. 2013. Role of Acid Blue 25 Dye as Active Site for the Adsorption of Cd^{2+} and Zn^{2+} using Activated Carbons. *Dyes and Pig.* 96: 459.
- [3] Arif, N., Yadav, V., Singh, S., Singh, S., Ahmad, P., Mishra, R. K., Sharma, S., Tripathi, D. K., Dubey, N. K., and Chauhan, D. K. 2016. Influence of High and Low Levels of Plant-beneficial Heavy Metal Ions on Plant Growth and Development. *Front. Environ. Sci.* 4: 69.
- [4] Bansal, S. L., and Asthana, S. 2018. Biologically Essential and Non-Essential Elements Causing Toxicity in Environment. *J. Environ. Anal. Toxicol.* 8: 1-5.
- [5] Obasi, P. N., and Akudinobi, B. B. 2020. Potential Health Risk and Levels of Heavy Metals in

- Water Resources of Lead–zinc Mining Communities of Abakaliki, Southeast Nigeria. *Appl. Water Sci.* 10: 184.
- [6] Habib, A., Islam, A., Islam, N., and Alam M. S. 2007. Removal of Copper from Aqueous Solution Using Orange Peel, Sawdust and Bagasse Pak. *J. Anal. Environ. Chem.* 8(1): 2-21.
- [7] Marey, A. 2020. Synthesis Composite of TiO_2 / Chitosan and TiO_2 / Bentonite for removing turbidity from Ismailia Canal as Water Treatment Plant. *African Journal of Chemical Education (AJCE)*. 10(1): 124-134.
- [8] Marey, A. 2019. Effectiveness of Chitosan as Natural Coagulant in Treating Turbid Waters. *Revista Bionatura*. 4(2): 856-860.
- [9] Marey, A. 2021. Usage of Cicer Arietinum as a Local and Eco-friendly Natural Coagulant in Sewage Treatment and Its Ability to Increase the Formation of Floc Process. *Revista Bionatura*. 6(3): 1939-1943.
- [10] Repoa, E., Warcholc, J. K., Kurniawana, T. A., and Sillanpaa, M. E. T. 2010. Adsorption of Co (II) and Ni (II) by EDTA- and/or DTPA- Modified Chitosan Kinetic and Equilibrium Modeling. *J. Chem. Eng.* 6: 73.
- [11] Gupta, N., Kushwaha, A. K. Chattopadhyaya, M. C. 2011. Adsorption of Cobalt (II) from Aqueous Solution onto Hydroxyapatite/zeolite Composite. *Adv. Mat. Letter.* 2(4): 309.
- [12] Caramalău, C., Bulgariu, L., Macovean, M. 2009. Cobalt (II) Removal from Aqueous Solutions by Adsorption on Modified Peat Moss. *Chem. Bull.* 54(68): 1.
- [13] Kang, W., Wang, A. 2013. One-step Fabrication in Aqueous Solution of a Granular Alginate-based Hydrogel for Fast and Efficient Removal of Heavy Metal Ions. *J. Polym. Res.* 20: 110.
- [14] Mahmoud, G. A., Abdel-Aal, S. E., Badway, N. A, Elbayaa, A. A, and Ahmed, D. F. 2017. A Novel Hydrogel based on Agricultural Waste for Removal of Hazardous Dyes from Aqueous Solution and Reuse Process in a Secondary Adsorption. *Polymer Bulletin.* 74(2): 337.