

Copper ions adsorption from aqueous solution using perlite

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ANNOTATION

There were explored adsorption properties of natural mineral of Georgia– perlite in the treatment process of aqueous solution of copper. There was studied the dependence of Cu (II) adsorption degree from adsorbent dosage, contact time and solution pH on both initial (not-expanded) and foamed (expanded) perlite. Under optimum conditions (pH = 1.9, contact time 1 h and adsorbent amount 5 g) adsorption capacity and adsorption degree of copper were equal to 11,2mg/g and 94%. It is showed that foamed perlite manifests perfect adsorption properties for copper removal from aqueous solution and it can be recommended as a potential adsorbent in the mentioned process.

Key words: foamed perlite, copper, adsorption, adsorption degree.

I. INTRODUCTION

Gradual development of mining and processing technology in mining extraction, coal, chemical, metallurgical and other industries leads to steady increase of environmental pollution. The major part of industrial enterprises uses engineering processes leading to formation of large quantities of waste waters containing heavy metal ions distinguished by high toxicity.

Environment protection and analytical test of waste waters are among main measures taken across the globe. Heavy metals represent potential problem for water and soil quality, plants, animals and human life. They may pose a threat to the health even when their concentrations don't exceed allowable limits, as far as it is known that heavy metals are accumulated in biological systems [1]-[4].

Among heavy metals copper is usually considered as non-toxic for human in the range of low concentrations (<5 mg/dm³). However, its presence in the organism in higher concentration leads to Wilson disease, as well as kidney, liver, myocardium diseases etc. [5]-[6]. Some authors [7]-[8] recommend 1,5 mg/dm³ as a maximum allowable concentration of Cu(II) in drinkable water.

Based on the above-mentioned, study and development of simple engineering processes of waste waters purification from heavy metal ions (HMI) is of apparent interest. Many methods, both conventional and unconventional, such as chemical deposition, solvent extraction, ion exchange, photoextraction, reversed osmosis, electrodialysis, ultrafiltration, adsorption etc. [9]-

[10]; have been used for HMI removal from industrial waste waters.

Adsorption method is considered as one of the most important ways of waste waters purification from HMI [11]-[12]-[13]. The highest attention is given to sorption system, where cheap, effective, natural aluminosilicates and minerals of different structure are used as sorbents [14]. Perlite is among such minerals. Perlite is a natural, glasslike, volcanic material, which is chemically inert, environmentally safe and economical. Among volcanic rocks perlite is featured by more than 1% presence of constitutional water. This water attach perlite a swelling (extending) ability when heated. It reduces mineral melting point and acts as an extending agent in molten state. While extending perlite disintegrates into ball-shaped grains with 4-20 times volume gain and 70-90% porosity [15].

The foamed perlite is an important material used in different industries: in construction – as heat-insulating, fire-proof and superlight material, in agriculture – as a root medium and soil conditioner, in textile industry – as a bleaching agent, in medicine – for pharmaceuticals filtration, in ecology – for water bodies and land surface cleaning and for drinkable water filtration, in chemical industry – as an adsorbent etc [16].

The goal of the present work is to explore adsorption potential of Georgian foamed perlite for Cu (II) ions removal from aqueous solution and to study the impact of adsorbent dosage, contact time and medium pH on adsorption efficiency.

Paravani perlite deposit, well-known in Georgia is located at the 130 km distance from Tbilisi to the southwest, at the boundary of Tsalka and Ninotsminda districts, at 2100 m height from sea level, in the vicinity of Paravani lake, the largest lake of Georgia. Deposit reserves are quite solid and amount 23000000 tons. Extraction, processing and sale of the mentioned raw material is implemented by Paravanperlite LLC. Characteristics of its product are confirmed by laboratory tests conducted by “Silbrico corporation” in 2011. Perlite of this deposit is used for production of two products: foamed perlite and filtration perlite powder. Foamed perlite is obtained through raw material heating up to 900-1000°C, in the course of which the volume increases 30 times that predetermines its unique

properties. Both forms of manufactured perlite are used in all above-mentioned branches of national economy. It should be noted that locally produced perlite powder is the best filtering material. It ideally filters both non-alcoholic and alcoholic beverages and food products (wine, beer, fruit juices etc.). It is successfully used for filtering drinkable and waste waters that enables many consumers to step back from import of similar materials.

II. OBJECTS AND METHODS

Samples of both initial and foamed perlites obtained from Paravanperlite LLC, have been used without any preliminary treatment in Cu(II) adsorption process. Chemical composition of Georgian perlite is given in the Table. Density of this perlite is 90-120 kg/m³, pH – 6-7, moisture ≤3%, and grain size 0,63-4,0mm.

Table 1: Chemical composition of perlite

Components	%
SiO ₂	70-75
Al ₂ O ₃	12-14
K ₂ O	3-5
Na ₂ O	3-5
Fe ₂ O ₃	1
MgO	1
CaO	2

For preparation of standard solution the electrolytic copper was weighed, dissolved in nitric acid and filled two times with distilled water up to 1 liter.

III. EXPERIMENTAL PART

Cu(II) adsorption experiment was conducted on both initial (non-expanded), and foamed perlite at given pH, contact time and adsorbent dosage level. In order to define the optimum quantity of perlite needed for Cu (II) ions removal, different amounts of adsorbent, namely 1, 2, 3, 4, 5, 6, 7 g were placed into containers and poured by copper solution under study. Containers were closed, shook up for 1 hour and then filtered. For determination of optimum contact time, 5g of adsorbent were placed into container, poured with 100 ml of standard copper solution and tested. Samples were collected after 15, 30, 60, 120, and 180 minutes. In the mentioned tests the reaction medium pH was equal to 1,9.

In order to investigate medium pH impact on copper adsorption, pH was brought up to 2, 3, 5, 7, 8 using 1M of NaOH solution and was poured into containers containing 1 g of adsorbent. Adsorbent was taken in 1 g amount to make this dependence more evident, since under optimum conditions (5 g of adsorbent, pH = 1,9) the Cu(II) adsorption degree was high (94%). After mixing the contents were filtered and the filtrate was analyzed on copper concentration. Analyses were conducted according to atomic adsorption (AAC, Perkin-Elmer Analyst - 200)

and chemical methods. Solution pH was measured on Seven Excellence, Multiparameter. Ions amount adsorbed per 1 g of sorbent (volume capacity) A mg/g and solution adsorption degree R% were calculated according to formulas:

$$A = \frac{C_0 - C}{m} \cdot V \text{ mg/g}$$

$$R = \frac{C_0 - C}{C_0} \cdot 100\%$$

where C₀ – initial concentration, mg/dm³;
C – concentration after test;
m – sorbent mass, g;
V – volume of purified solution, dm³.

IV. RESULTS AND DISCUSSION

Regularities of aqueous solution purification from copper ions using adsorption method in the presence of local mineral – perlite are investigated. The impact of adsorbent dosage, contact time and medium pH on perlite adsorption ability is studied.

The impact of adsorbent quantity is one of the most important parameters of adsorption processes. Test results showed that adsorption degree on initial perlite was low and maximum values reached 32,5%. That's why the follow-up studies were conducted on foamed perlite. As is seen from Fig.1, copper adsorption degree on foamed perlite gradually increases with adsorbent dose escalation from 45 to 98% and becomes almost constant, when the dosage is 5-7 g, and volume capacity is 11,2 mg/g. It may be explained by the fact that with increase in adsorbent quantity the bigger surface of adsorbent becomes accessible for Cu(II) adsorption [17]. As far as the difference in adsorption degree between 5 and 7 g was not so high, 5 g of adsorbent was selected as an optimum dosage for follow-up experiments.

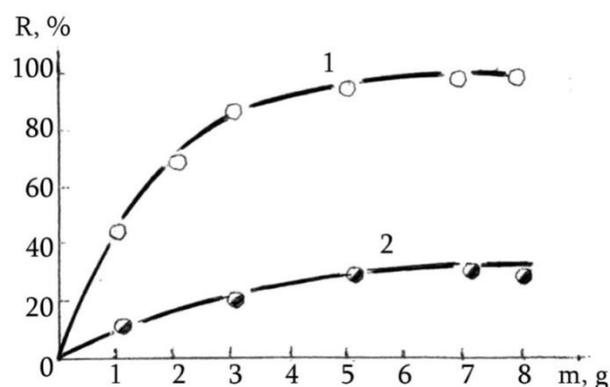


Fig. 1. Adsorbent dosage (m, g) impact on Cu(II) adsorption degree (R, %)
1 – foamed perlite, 2 – initial perlite, pH = 1,9, τ = 1h, t = 20°C

Contact time impact on copper adsorption is given in Fig. 2. This figure shows that metal concentration in aqueous solution reduces during 60 minutes, and stays

constant afterwards. This fact points at quick adsorption of copper in the process beginning. 60 minutes were taken as an optimum contact time [18].

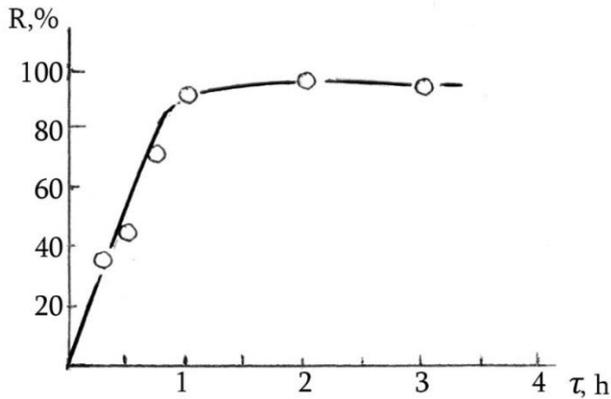


Fig. 2. Contact time impact on Cu (II) adsorption degree

pH = 1,9, m = 5g, t = 20°C

Fig. 3 shows the impact of medium pH on copper adsorption. As is seen from the diagram, at low numbers of pH copper adsorption percentage is low. Cu(II) adsorption on foamed perlite slowly increase in the range of pH = 2-6, and maximum is reached at pH = 7,5-8,0, when adsorption degree was 94,7%, while volume capacity – 56,7 mg/g. It is established that such a nature of adsorption degree dependence on medium pH is associated with the state change of active sorbent centers. At low quantities of pH hydrogen ions totally dominate and adsorbent surface promotion takes place that assists electrostatic repulsion of metal ions and lowering of their adsorption. Electrostatic repulsion reduces with pH increase due to decrease of positive charge density at the surface that leads to metal ions surface adsorption growth. When pH is more than 8,0, Cu(II) deposits as an hydroxide, which lowers adsorption rate and, respectively, copper removal percentage [19].

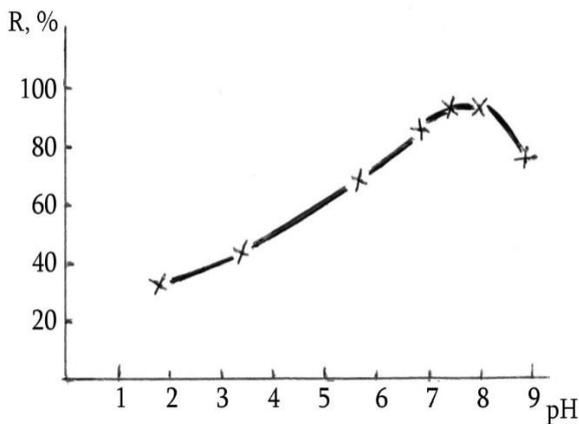


Fig. 3. Impact of medium pH of solution under study on Cu (II) adsorption degree

m = 1g, τ = 1h, t = 20°C

V. CONCLUSIONS

In this work for the first time there were explored the opportunities of foamed perlite use for adsorption removal of Cu(II) from aqueous solution. Dependences of adsorption ability and adsorptive capacity on medium pH, adsorbent dosage and contact time were studied. Optimum conditions for process conduct were selected, namely: adsorbent amount – 5 g, contact time 60 min and medium pH = 1,9. Under these conditions copper adsorption degree was 94%, and volume capacity – 11,2 mg/g. It was shown that the foamed perlite of local origin can be successfully used as an adsorbent for Cu(II) removal from solution.

VI. REFERENCE

- [1] Ahuwalia S.S. and Coyal D., (2005): Removal of heavy metals by waste tea leaves from aqueous solution, *Eng.Lige Sci.*, 5:158-162.
- [2] Pamukoğlu, M.Y., Kargı, F., (2009). Removal of Cu (II) ions biosorption to powdered waste sludge (PWS) prior to biological treatment in an activated sludge unit: A statistical design approach, *Bioresour. Technol.* 100:2348-
- [3] Ong, S., Seng, C. and Lim, P., Kinetics of adsorption of Cu (II) and Cd (II) from aqueous solution on rice husk and modified rice husk. *Electronic J. Environ. Agric. Food Chem.*, 1764-1774 (2007).
- [4] Marais Barros, A. J., Prasad, S., Duarte Leite, V. and Gouveia Souza, A., The process of biosorption of heavy metals in bioreactors loaded with sanitary sewage sludge. *Braz. J. Chem. Eng.*, 23, 153-162 (2006).
- [5] Ajmal, M., Rao, R.A.K., Khan, M.A., (2005). Adsorption of copper from aqueous solution of *Brassica campestris* (mustard oil cake), *J. Hazard. Mater.* 122 (1-2):177-183
- [6] Bhattacharyya, K.G., Gupta, S.S., (2006). Kaolinite, montmorillonite, and their modified derivatives as adsorbents for removal of Cu (II) from aqueous solution, *Se. Purif. Technol.* 50(3):388-397
- [7] Gök, Ö., Özcan, A., Erdem, B., Özcan, A.S., (2008). Prediction of the kinetics, equilibrium and thermodynamic parameters of adsorption of copper (II) ions onto 8-hydroxy quinoline immobilized bentonite, *Colloids Surfaces A: Physicochem. Eng. Aspects* 317:174-185
- [8] Aman, T., Kazi, A.A., Sabri, M.U., Bano, Q., (2008). Potato peels as solid waste for the removal of heavy metal copper(II) from waste water/industrial effluent. *Colloid Surface B.* 63:116-121
- [9] Kim T.Y., Park S.K., Cho S.Y., Kim H.B., (2005): Sorption of heavy metals by brewery biomass, *Korean J. Chem. Eng.*, 22:91-98.
- [10] Vieira, M.G.A., Almeida Neto, A.F., Gimenes, M.L., da Silva, M.G.C., (2010). Sorption kinetics and equilibrium for the removal of nickel ions from aqueous phase on calcined Bofe bentonite clay, *J. Hazard. Mater.* 177:362-371.
- [11] Unlü, N., and Ersoz, M., Adsorption characteristics of heavy metal ions onto low cost biopolymeric sorbent from aqueous solution. *J. Hazard. Mater.*, 136, No. 2, 272-280 (2006).

[12] Nwabanne, J. T. and Ibbokwe, P. K., Kinetics and equilibrium modeling of nickel adsorption by cassava peel. *J. Eng. Applied Sci.*, 3, 829-834 (2008).

[13] Lavania U.C. *Currentscience*, 2004, v.86, #1, pp. 11-14.

[14] Kalabegashvili N.G., Ioseliani D.K., Balarjishvili G.I., Samkharadze L.O., Tsiskarishvili R.P., Dolidze A.B., (2017). Waste water purification from heavy metals with the use of local clays and mineral Brucite. *Proceedings of the Georgian National Academy of Sciences*, 43:162-164.

[15] Alkan, M. and Dogan, M., in: *Encyclopedia of Surface and Colloid Science*. Dekker, New York, pp. 3945-3958 (2002).

[16] Zorpas, A.A., Vlyssides, A.G., Loizidou, M., (1999). Dewatered Anaerobically-Stabilized Primary Sewage Sludge Composting: Metal Leachability and Uptake by Natural Clinoptilolite Commun. *SoilSci. Plant Anal.*, 30 (11&12):1603-1613

[17] Gence, H., Tjell, I.C., M. Conchie, D. and Schilling, O. Adsorption of arsenic from water using natural red mud. *J. Colloid Interf. Sci.*, 264, 327-334 (2003).

[18] Pelleria F.M., Giannis A., Kalderis D., Anastasiadou K., Stegman R. Adsorption of Cu (II) ions from aqueous solution on biochars prepared from agricultural by-products. *Journal of Environmental Management*, 96:35-42.

[19] Shaikhiev I.G., and Bagauva A.I., (2014): Removal of iron(III) ions by extracts of oak bark and leaves and study of morphology and kinetics of waste sedimentation, *Water, chemistry and ecology.*, 3:70-84.