Fe^{2+} Removal from Aqueous Solution Using Expanded Perlite

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Abstract— Adsorption properties of Georgian expanded perlite prepared on the basis of perlite – natural mineral of Georgia in the process of aqueous solution purification from bivalent iron ionswere investigated for the first time in the work. The dependences of adsorption degree and volume capacity on change of solution pH, adsorbent dosage, contact time and adsorbate concentration were studied. Tests were mainly conductedunder dynamic and static conditions. Optimum conditions for Fe2+ adsorption on expanded perlite have been determined. Maximal efficiency of iron adsorption degree was equal to 91%, and volume capacity – 1.82 mg/g. Expanded perlite shows excellent adsorption properties in the process of iron removal from aqueous solution.

Index Terms— expanded perlite, adsorption, iron, adsorption degree.

I. Introduction

Heavy metals present in the industrial waste waters are toxic and are not amenable to biological decay so they can accumulate in living tissues. They represent problem for water and soil quality, for plants, animals and human life.

Iron is the most widespread element on the Earth next to aluminum. Its amount equals to 4% of Earth mass. While touching iron-containing minerals during its movement, water dissolves iron compounds, which may occur in natural waters in both soluble and suspended or colloidal state. Iron can also hit the waste waters resulting from current engineering processes in the enterprises [1].

According to standard data, iron content in the water has not to exceed 0,3 mg/l. Excessive iron content leads to negative effect on human skin, has an influence on blood composition, provokes allergic reactions development, and can cause internal organs damage etc.

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In this regard the research and development of simple technological methods for waste water purification from iron ions is very topical.

There are known lots of modern, conventional and non-conventional methods of waste water purification: chemical, membrane, ion-exchange, electrochemical, extraction etc. At this moment they frequently use coagulation and flocculation combined with flotation and filtration [2].

But the majority of these methods has a number of shortcomings, such as: formation of secondary pollution (which creates a disposal problem), high initial cost due to consumption of large quantities of chemicals and high expenditures for technical maintenance and exploitation.

On the other hand, the adsorption process is physically more efficient and economical. The biggest attention is given to sorption systems, in which adsorbents stand out by local accessibility, high adsorption ability and economical efficiency. Natural, effective, cheap alumo silicates and minerals are used as adsorbents [3], and perlite is one of such minerals.

Perlite is a natural, glasslike, volcanic material mainly consisting of volcanic silica(silicon dioxide) and alum earth with high porosity and specific surface. It is chemically inert and environmentally friendly.

Perlite is distinguished by water availability, which is present in two: free and constitutional (bound) forms in the initial perlite. If a constitutional water content is more than 1%, that attaches perlite the ability to expand when heating up to 900-1000°C. During expansion (popping) perlite decomposes into spherical grains with 4-20 times increase in volume and 70-90% porosity [4].

The expansion process causes one of the most distinctive characteristics of perlite – its white color, while a color of raw perlite may vary from transparent light grey to glazed black.

The expanded perlite is used in different sectors of national economy: construction, agriculture, textile industry, medicine, chemical industry, ecology and for drinking water and food product filtration.

The given work is devoted to the research of adsorption capacity of Georgian perlite. The effect of medium pH, adsorbent dosage, contact time, adsorbate concentration on iron ions adsorption degree from aqueous solution has been studied.

The perlite deposit known in Georgia is located south-west from Tbilisi, at 130 km distance, at the boundary of Tsalka and Ninotsminda district, in high-mountain region, in the vicinity of the largest lake of Georgia – Paravanilake.

The quarry is situated at 115 hectare area and deposit reserves are 23 million tons. Extraction, processing and selling of the mentioned raw material is implemented by

Paravanperliti LLC. Charactertistic of its product are verified by tests made by "Silbrico Corporation" in 2011 in USA. Expanded agroperlite and filtroperlite,which mainly differ from each other by size, should be mentioned among the products manufactured by this company. Both types of powders are obtained through raw material heating up to 900-1100°C, in the course of which the perlite volume increases 30 and more times.

Adsorption properties of expanded perlite during aqueous solution purification from copper ions have been studied by us and research data are given in the work [5].

II. OBJECTS AND METHODS

Expanded perlite samples have been obtained from Paravanperliti LLC. Data on chemical composition of Georgian perlite are given in the preceding article [5].

Density of the used perlite is 70-120 kg/m³, particle specific surface – 0,1145 m²/m, pH – 6-7, particle size – 0,140 mm.

Fe²⁺ containing solution under investigation has been prepared through mohr's salt dissolution in bidistillate, taking the given concentration into account.

III. EXPERIMENTAL PART

Series of experimentshas been carried out for comparison of adsorption properties of original and foamed (expanded) perlite under both dynamic and static conditions in regard to iron ions adsorption from aqueous solution.

The effect of adsorbent dosage, contact time, medium pH and adsorbateconcentration on Fe²⁺ adsorption degree and volume capacity have been studied.

In order to determine the optimum quantity of expanded perlite in regard to iron ions removal from aqueous solution, different amounts of adsorbent – 1, 2, 3, 4, 5, 6, 7 g were placed in containers and covered with iron solution under investigation. Containers were lidded, shaken for 1 hour and then filtered and analyzed. There was selected the optimum amount of adsorbent that was equal to 5 g.

In order to determine the optimum contact time, 5 g of adsorbent were placed into container, covered with 100 ml of standard Fe²⁺ solution and tested. Samples were gathered in 30, 60, 120 and 180 minutes.

For determination of medium pH effect on iron adsorption, pH was adjusted to 2, 3, 5, 6, 7 with the use of 1M HCl (pH = 2, 3, and 4) and 1M NaOH (pH = 6,7). 100 ml of solution with the given pH was poured into container, in which 5 g of expanded perlite was already placed, and was shaken for 1 hour, filtered and analyzed.

In order to investigate the dependence of adsorbate concentration on adsorption activity, optimum amount – 5g of adsorbent were placed into container, covered with 100 ml of Fe²⁺ solution of different concentrations – 50, 100, 200, 300 mg/l, shaken for 1 hour and filtered.

We have conducted the tests on original and expanded perlite under static conditions, as well. 5 g of adsorbent were placed into container, covered with 100 ml of standard Fe²⁺ solution with 100 mg/l concentration, and left for 24, 48 and 72 hours at room temperature.

Filtrates were analyzed using atomic-adsorption (AAC Perkin-Elmor Analyst 200) and chemical methods.

The amount of Fe²⁺ ions adsorbed per unit of adsorbent weight (1g) A, mg/g and metal ions adsorption degree R, % were calculated according to following equations:

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

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

Where C_o – initial concentration of solution, mg/dm³;
C –aposteriori (after the test) concentration;
m –sorbent weight, g;
V –volume of purified solution, dm³.

IV. RESULTS AND DISCUSSION

Adsorption potential of initial and expanded perlite in the process of Fe²⁺ ions removal from aqueous solution has been studied in the given work. As far as the majority of perlite samples has a high content of silica (more than 70%) and alum earth, they stand out by high adsorption properties [6]. Adsorptive character of perlite is caused by silanol groups, formed by silicon atoms at perlite surface. Silicon atoms at perlite surface have a tendency for maintaining tetrahedral coordination with oxygen. They complete this coordination through attachment to monovalent hydroxyl groups, forming silanol groups, which cause adsorptive character of perlite [7].

The effect of adsorbent dosage, contact time, medium pH and adsorbate concentration on adsorption degree and volume capacity has been studied in the work.

Adsorbent dosage is one of the essential parameters of adsorption processes, since it determines adsorptive capacity at prescribed value of adsorbent initial concentration and under given conditions. In Fig. 1 there is shown an effect of adsorbent dosage on Fe²⁺ adsorption percentage, for original and expanded perlite.
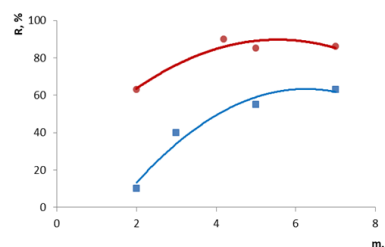

Fig. 1. Adsorbent dosage (m, g) impact on Fe (II) adsorption degree (R, %). I – initial perlite, II– foamed perlite, pH =5,0, τ =1h, t = 20°C

As is seen from the Figure, with increase of adsorbent dosage an adsorption percentage rises for both adsorbents from 12 to 64% and from 77 to 91%and becomes almost constant at 5-7 g dosage, and volume capacity increases from 0,63 to 1,5 mg/g and from 3 to 13 mg/g, respectively, as well. This fact may be explained by the reason that the presence of active centers at adsorbent surface rises with increase of adsorbent dosage [8]. As far as for initial perlitethe relatively low values of Fe²⁺ adsorption percentage were obtained, further studies were conducted at expanded perlite.

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In Fig. 2 there is shown the dependence of Fe^{2+} adsorption degree at expanded perlite on adsorbate (standard solution) concentration.
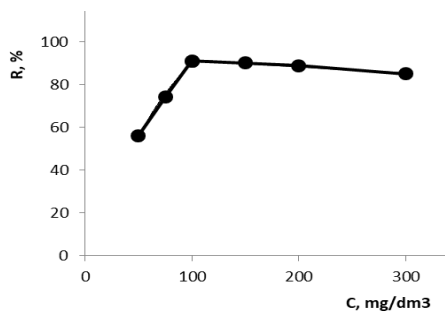

Fig. 2.the influence of the concentration of the solution on the degree of adsorption Fe (II) adsorption. pH = 5,0, m = 5g, t = 20°C, τ =1h.

Tests have been conducted with the use of wider range of adsorbate concentration (from 5 to 300 mg/l). As is seen from the graph, Fe^{2+} adsorption degree rises with concentration increase and reaches a maximum at 100 mg/l concentration, then it slightly drops, so 100 mg/l has been selected as an optimum concentration.

Shaking time effect on Fe^{2+} adsorption (Fig. 3) shows that iron ions concentration in aqueous solution reduces for the first 60 minutes with time increment, and adsorption degree reaches a maximum when t = 60 min, and then reduces. One may assume that bivalent iron after a definite test time (>1 hour) has been exposed to oxidation into trivalent iron that makes substantial contribution to mixture's ionic strength upward the latter. At that, ionic strength increase has lead to adsorption decrease [9].]
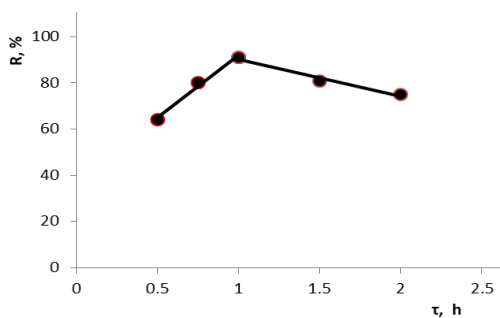

Fig. 3. Contact time impact on Fe (II) adsorption degree. pH = 5,0, m = 5g, t = 20°C.

Medium pH effect on Fe^{2+} adsorption degree from aqueous solution on expandedperlite was investigated, as well. In order to more obviously demonstrate the mentioned effect, tests were conducted under conditions of low percentage of Fe^{2+} adsorption. Based on the tests conducted by us, there was taken the adsorbent in the quantity of 2 g, for which the adsorption percentage was 64%.

In order to study medium pH effect in the Fe^{2+} adsorption process, 100 ml of standard solution (with concentration 100 mg/l) and 2g of expanded perlite have been studied in the range of pH = 2-7, while contact time was 1 hour (Fig. 4).
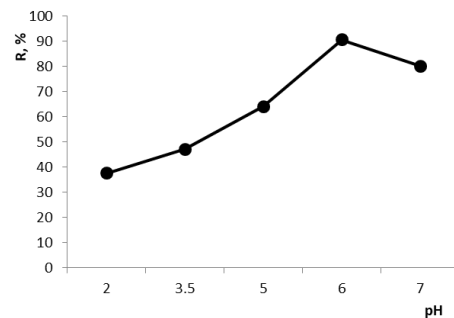

Fig.4. Fig. 4. Impact of medium pH of solution under studyonFe (II)adsorption degree. m = 5g, τ = 1h, t = 20°C

With the purpose of pH variation a standard solution (pH of which is 5,0) was acidified through addition of 1M HCl and alkalized through addition of 1M NaOH. As is seen from Fig. 3, Fe^{2+} adsorption degree and, therefore, volume capacity rise from 37,5 to 91% with increase of pH, and decrease afterwards. It is established that such a nature of adsorption degree dependence on medium pH is caused by change of state of sorbent's active centers. At small values of pH the adsorption percentage is low due to increase in positive charge (proton) density at the adsorbent surface that leads to electric repulsion of metal ions. With increase of pH an electric repulsion is getting smaller due to reduction of positive charge density and metal adsorption increases. When pH is more than 6,5, metal deposits as a hydroxide at the adsorbent surface and reduces Fe^{2+} adsorption degree [10].

We have already conducted tests on original and expanded perlite under static conditions.

As the results show, Fe^{2+} adsorption degree was low, was equal to 21,6-22,0% for original perlite and almost was not changed in time, while in case of expanded perlite Fe^{2+} adsorption degree was 27,2% and was almost the same during 24, 48 and 72 hours.

V. CONCLUSIONS

The opportunities of Georgian expanded perlite use for adsorptive removal of Fe^{2+} from aqueous solution were investigated for the first time in this work and there was found out that perlite may be successfully used as an adsorbent in the mentioned reaction. The dependences of adsorption capacity on medium pH, adsorbent dosage, contact time and adsorbate concentration were studied. The optimum conditions of the process are selected. Under these conditions iron adsorption degree and adsorption capacity on expanded perlitewere equal to 91% and 1,82 mg/g, respectively.
Use

REFERENCES

[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] Pamukoglu M.Y., Kargi F. (2009). Removal of Cu(II) ions biosorption onto powdered waster sludge (PWS) prior to biological treatment in inactivated sludge unit: A statistical design approach, Bioresour. Technol. 100:2348-2354.
[3] Kalabegashvili N.O., Ioseliani D.K., Balarjishvili G.I., Samkharadze L.D., Tsikarishvili 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.

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

[5] Ioseliani D.K., Balarjishvili G.I., Kalabegashvili N.O., Samkharadze L.D., Nonikashvili N.U., Mikadze I.I. (2020). Copper Ions Adsorption from Aqueous Solution using Perlite. Inter. J. of New Technology and Research (IJNTR), vol. 6, 73-77, 2454-4116, pp. 30-32.

[6] Dogan M., Alkan M., Ongher I. (2000). Adsorption of methylene blue from aqueous solution onto perlite. Water Air Soil Pollut., 120 (3-4), 229-248.

[7] Acemioglu B. (2005) Bath Kinetic Study of Sorption of Methylene Blue by Perlite. Chem. Eng. J. 106(1), 73-81.

[8] 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).

[9] Alkan M., and Dogan M. Adsorption of copper (II) onto perlite. J. Colloid Interface Sci., 280-291 (2001).

[10] 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.

[11] Ardali Y., GamzeTuran N., Temel E.A. (2014) Cu (II) Removal from Industrial Waste Leachate by Adsorption Using Expanded Perlite. Journal of the Institute of Natural Applied Science, 19(1-2): 54-61.