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S. Satayeva[1], F.Zh. Akhmetova[1*], R. Jusupkaliyeva[1], D. Nazarova[1], I. Kazarinov[2], M. Mambetova[1], B. Salim[1], Y. Hahaleva[1]

[1]Zhangirkhan West-Kazakhstan agrarian technical university, Uralsk, Kazakhstan
[2]Saratov State University N G Chernyshevsky, Saratov, Russia
*e-mail: firuza.92@mail.ru

Study of the new composite sorbents for water treatment

Abstract: Water pollution has become one of the key global environmental problems. Heavy metal ions are the main pollutants of water. Current study focuses on the manufacture of a highly efficient filter that absorbs heavy metals for water purification using inexpensive materials. The article discusses and shows the possibilities of using new sorption materials for water softening purposes. Experimental data on the study of sorption properties of the developed material are presented. Possible ways to improve the water treatment existing scheme of the enterprise are proposed. The study object was natural mineral sorbents, promising for use in water purification and conditioning processes. The work aim was to experimentally evaluate the use effectiveness of natural mineral sorbents for water purification. Research by using modern physical and chemical methods, it has been shown that natural mineral sorbents effectively purify water from pollution. The most promising natural mineral sorbents turned out to be the flask of the Taskala deposit of the West Kazakhstan region to purify water from heavy metal ions. Natural mineral sorbents purify water from excess iron ions and have pronounced sorption properties.

Key words: opoka, water softening, natural mineral sorbents, siliceous microporous sedimentary rocks.

Introduction

Heavy metal pollution threatens the environment and human health, therefore the effective removal of these toxic pollutants from various complex substrates is of great importance. Until now, adsorption is still one of the most effective approaches [1].

Achieving the required quality of various compositions groundwater purification involves a variety of technological solutions. The technological scheme choice should be made on the basis of a comprehensive analysis of groundwater quality indicators, considering the efficiency of water treatment schemes established in practice. Effective measures are improvement of technological processes, reduction of specific water consumption, reduction of reagent consumption.

To date, various methods of iron removal are used to obtain drinking-quality water [2–4]. Methods based on filtration through modified loading and purification technology are often used, including aeration and filtration through sand loading. Their disadvantages include abrasion, short operating time of the catalytic layer, low cleaning efficiency by the end of the filtration cycle, a large amount of water required for filter regeneration [5]. Sorption is a simple and effective way to remove iron and manganese cations from water. Particular attention is paid to sorption systems, where natural materials are used as sorbents: minerals of various origins and structures. The presence of local effective natural sorbents makes it possible to expand the possibilities of implementing adsorption technological processes for local groundwater treatment systems [6,7].

The opoka have proven themselves as sorbents in the purification of natural and washing waters [8]. This is due to their porous structure with a predominance of micro- and mesopores. They are formed by silica particles, the mass content of which ranges from 75 to 92% depending on the deposit. The density ranges from 1100 to 1600 kg/m^3, the porosity is about 55%. The opoka mainly consist of clay minerals, but at the same time they differ in lightness, rough surface of a cancellous and squamous fracture [9,10].

Materials and methods

The study objects are the natural sorbent – the opoka of the Taskala deposit and the water of the Shagan river of the West-Kazakhstan region.

Siliceous rock – the opoka of the Taskala deposit is a light, hard, microporous rock. According to geological data, opoka occurs in Paleogene and Cretaceous sediments, are formed in marine basins due to compaction and cementation of diatomites and trepels. Their density is 1.3-1.5 g/cm^3.

The main components of the opoka are silicon and aluminum oxides, the contents of which range from 44.351% to 48.126% for SiO_2 and from 38.928% to 39.028% for $A1_2O_3$. The content of SiO_2 and Al_2O_3 corresponds to the values of the maximum permissible concentrations in clays used in the production of sorbent for water purification. However, magnesium and sulfur (VI) oxides play an important role, which are contained in small amounts, in the sedimentary rock of the Taskala deposit, their content reaches 1.149%. These impurities are undesirable, as they negatively affect the quality of the sorbent for water purification from heavy metals. Proceeding from this, it can be concluded that while the Taskala deposit is most suitable as a natural sorbent for removing heavy metal cations from water.

– X-ray phase analysis was used, which allows to determine the qualitative and quantitative composition of the clinker with high accuracy to control the quality of the obtained sorbent. X-ray phase analysis of the flask was performed on a diffractometer D2 Phaser (Bruker, USA). The sorbent under study was averaged, and a sample of 20-25 g was taken from it, which was crushed into fine grits in a metal mortar. After averaging the grits, 5-7 g of material was taken from it, which was crushed in the agate composition of the raw mixture and clinker was carried out in a powder mortar by periodic screening on a 006-sieve using a soft brush. The remaining residue on the sieve was ground again and sieved until the initial sample of the material was completely passed. The test substance sample was stuffed into a cuvette made of organic glass and having a diameter of 20-25 mm with a recess on one of the planes up to 3 mm. The stuffing was carried out gradually, in layers, until the recess in the cuvette was completely filled, after which the surface of the material under study was carefully aligned so that the material planes and the collar of the cuvette ring coincided. A cuvette filled with material was installed in a goniometer sample holder, where the material was irradiated with X-rays with a certain wavelength at a variable angle of incidence.

The sorption efficiency of natural mineral sorbent was studied under flow conditions. To do this, the mineral, crushed to the required particle size, was placed in a plastic column with a diameter of 6 cm and a height of 23 cm between two polypropylene gaskets on top and bottom to eliminate the leaching of small particles of material from the filter. The introduced material volume was 0.5 liters. The water supply rate to the filters was set in the range of 2-3 ml/min.

Concentrations of divalent copper ions of 0.5 mg/l, 5 mg/l and 10 mg/l were created in model solutions by introducing the necessary amounts of 1M copper sulfate solution. The copper content in water was determined by colorimetric method with sodium diethyldithiocarbamate

Results and discussion

The phase composition of the siliceous microporous sedimentary rock of the Taskala deposit is shown in Figure 1.

In the technology of sorbent production for water purification, a range of various additives is widely used. One of these additives is carbon, which has a particle size of no more than 5 microns. Based on the chemical composition of the raw material (siliceous microporous sedimentary rock of the Taskala deposit), an X-ray phase analysis of the obtained flask was carried out. The carbon use as an additive makes it possible to increase technological efficiency and environmental safety. Thus, based on the conducted studies, it is advisable to use the flask of the Taskala deposit as a sorbent for removing heavy metal ions from water.

The suitability of water for drinking is primarily determined by its organoleptic properties. Therefore, at the first stage of the work, studies of the effect of the sorbent on these indicators were carried out. Table 1 demonstrates the organoleptic parameters and pH of the water before and after passing it through filters with a sorbent. The original tap water had increased color and turbidity.

Water treatment with a sorbent in filtration mode leads to a significant improvement in the organoleptic properties of water. The sorbents effectiveness for water purification was evaluated by comparing the organoleptic, physical and chemical, microbiological and toxicological parameters of the source, and treated water. Organoleptic and physical and chemical parameters were evaluated in accordance with the methods.

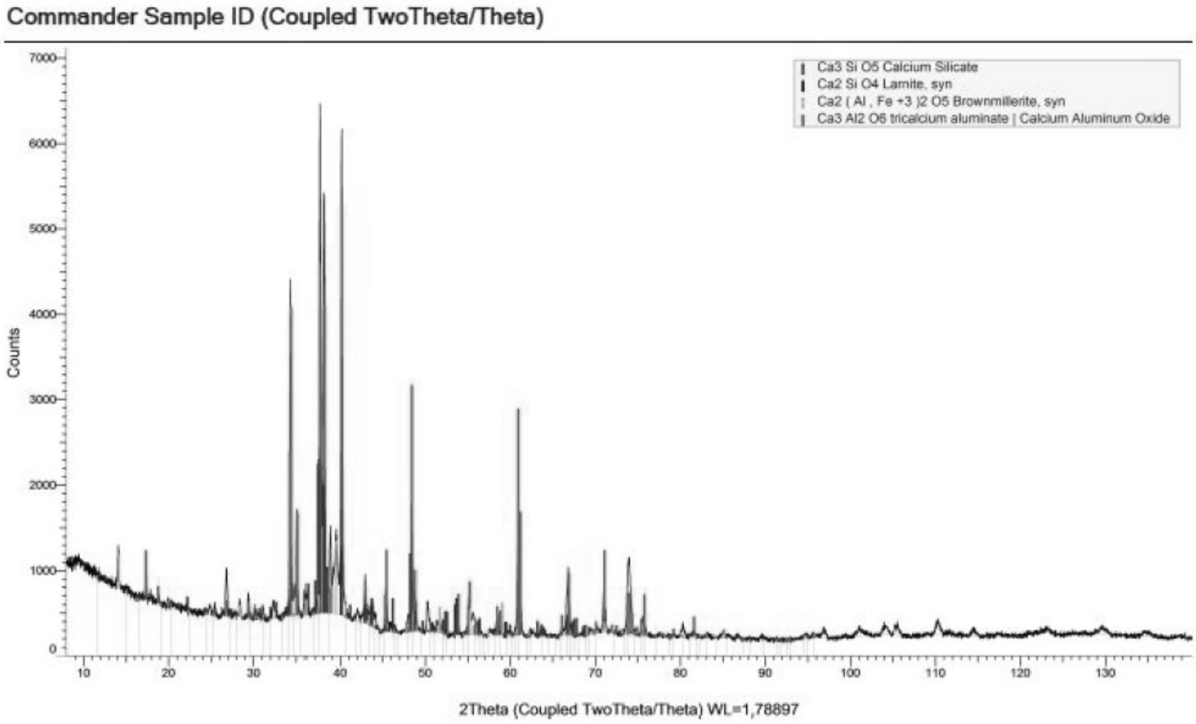

Figure 1 – Phase composition of the siliceous rock of the Taskala deposit

Table 1 – Organoleptic parameters of the Shagan River water

Indicators	Source water	Sorbent	Thermal modification of the sorbent at the		Standard 22.1.4.1074-01
			400 ºC	800 ºC	
pH	7.4	7.8	8.5	8.5	6-9
Aftertaste	3	0	0	0	2
Chroma	29	0	0	0	20
Turbidity	4	0	0	0	2.6
Smell	3	0	0	0	6.0-9.0

Iron and divalent copper ions were chosen as a model of heavy metals. The maximum permissible concentration of copper in drinking water is 1 mg/l, which is several orders of magnitude higher than the MPC of mercury, lead, and cadmium. This gives reason to believe that the effective sorption of copper will correspond to the effective sorption of other heavy metals.

The most typical result of secondary contamination of drinking water in distribution networks is a significant excess of iron ions, the usual is an excess of iron concentration by 1.5-3 times.

Table 2 presents the results of studying the use effectiveness of filters with sorbent for water purification from iron and divalent copper ions. The use effectiveness of filters with a support for water purification from heavy metal ions were studied, which are one of the priority pollutants of the hydrosphere. Divalent copper ions were used as a model toxicant.

It can be concluded that the use of filters with siliceous rock makes it possible to purify water from the excess content of iron ions and divalent copper.

Table 2 – Physical and chemical parameters of the water of the Shagan river

Indicators	Unit of measurement	Source water	Sorbent	Thermal modification of sorbent		Standard 22.1.4.1074-01
				400 ºC	800 ºC	
pH	-	7.4	7.8	8.5	8.5	6-9
General hardness	mg-eq./l	6.4	4.5	3.65	3.5	< 7
Iron	mg/l	0.32	0.22	0.18	0.013	< 0.3
Copper		0.90	0.38	0.29	0.28	< 1.0

The concentration of iron in water during water purification decreased from 0.32 mg/l to 0.18 mg/l – thermal modification of the sorbent at the 400 ºC: to 0.013 mg /l – thermal modification of the sorbent at the 800 ºC, and the concentration of copper, respectively, from 0.90 mg/l to 0.28 mg/l. This means that the sorbent cleans heavy metals well from water, thermal modification improves its sorption properties. The tables show that the heat-treated sorbent removes iron and copper ions from the water well. At the same time, a degree of purification of up to 95% is achieved. This means that the rock of the Taskala deposit is a suitable sorbent for water degreasing.

Conclusion

The conducted studies allowed to formulate the following conclusions: for water purification from heavy metal ions, the most promising sorbents are the siliceous microporous sedimentary rock of the Taskala deposit. Their efficiency remains at a high level with different initial parameters of the treated water (low and high hardness, color). The siliceous microporous sedimentary rock of the Taskala deposit exhibits specific activity in removing particles of radical and ion-radical nature from the water, significantly surpassing both flint and glauconite limestone in this respect. The studied sorbent purifies water from excess iron ions in the studied concentration range from 0.32 to 0.013 mg/l. Thus, the conducted studies have revealed that the natural rock of the Taskala deposit can be used as a sorbent for the removal of iron and copper ions. Water treated with a natural sorbent improves its biological properties due to deep purification from chemical contaminants, reduced toxicity, as well as enrichment with essential macro- and microelements. The investigated natural mineral sorbent – siliceous microporous sedimentary rock of the Taskala deposit is promising for use in systems and means of improving water quality.

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