Use of pure diatomite for the sorption of heavy metal ions

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Дата поступления:
4 Августа 2019

Принято на печать:
28 Августа 2019

Доступно онлайн:
6 Октября 2019

УДК: 628.3, 628.161

ANNOTATION

This article presents results according to purification of water based on diatomite sorbents. The results of the study of diatomite samples from two different regions shows that adsorption capacity, specific surface and the degree of extraction of the sorbent of Republic of Kazakhstan higher than Iranian diatomite.

Keywords: diatomite, sorption, sorbents, metal ions.

Introduction

There are various inorganic and organic adsorbents including activated carbon, natural and synthetic zeolites, clay minerals, diatomites, hematite, alumina and silica, ion exchange resins, humic acids, coir pith, chitosan, polymeric materials, and different biosorbents.

A significant amount of nutrients and organic matter falls into the water from agricultural land, pastures and livestock farms. All these problems can have a severe environmental impact on the fauna and flora of any country. In this regard, an important environmental problem today is the treatment of wastewater and industrial waters from toxic and heavy metal ions, as well as from other pollutants.

There are quite a few different ways of treating industrial wastewater, but the most promising are methods based on the use of natural minerals as adsorbents. The use of natural minerals for wastewater treatment is acceptable from an environmental and economic point of view, but often such materials do not have the necessary sorption properties and require modification. Among natural sorption materials, diatomite is of particular interest. The large deposits of diatomite in Kazakhstan is located in the Mugaldzhar region and this implies great prospects for using this natural object to solve many applied environmental problem. Diatomite is a siliceous fossilized skeletons of diatoms with the emergence as sedimentary rock in the nature. It is the most budding cheap adsorbent to substitute the others adsorbent, for instance, diatomite 500 times cheaper than activated carbon [1]. This mineral consists of an important quantities of silicon dioxide (SiO_2), with considerable amount of alumina (Al_2O_3) and ferric oxide (Fe_2O_3) [2]. It has a exceptional property which fabricate diatomite appropriate for the water purification [3-7], dyes [8-9] and antibiotics [10-11]. However, the adsorption characteristics of pesticides in aqueous solution onto diatomite have not been noticeably explored. Moreover, few investigations on the pesticide adsorption kinetics and its modeling were reported in the work [12, 13].

Raw diatomite from Mugaldzhar (Kazakhstan) and Iran brands (J-86-20) produced by company "Tolldace Maadanle Esfahan Co" was used in this investigation. Diatomite samples were used as a sorbent for purification heavy metals. Selected diatomite samples were studied using scanning electron microscopy (SEM), Infra-red (IR), Raman spectroscopy, Energy Dispersive X-ray (EDAX) and BET analysis.

Experimental part

To conduct experimental work on the extraction of Pb^{2+} ions from aqueous solutions, solutions of Pb^{2+} salt were prepared from analytically pure lead nitrate $Pb(NO_3)_2$ with a concentration of 100 mg/l. The laboratory work flow chart is shown in Fig. 1. To study the adsorption of Pb^{2+} ions on the surface of manufactured sorbents, adsorbent samples weighing 1 g were mixed with 100 ml of $Pb(NO_3)_2$ solutions. Then the resulting mixture was shaken for 5, 30, 120 min as it shown in Fig. 1.

After filtration process, the residual concentration of Pb^{2+} ions were determined in the filtrate by atomic adsorption spectrometry.

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Results and discussions

Table 1 shows the results of the analysis of the measurement of the specific surface of the Kazakhstan diatomite and diatomite from the Republic of Iran.

The obtained SEM images of diatomite prove that it contains up to 80-90% of voids, and the pore sizes in the skeletons of diatomite are from a few microns to pores smaller than 1 µm (Fig. 1).

SEM images of diatomite shows a clean surface with open pores and connected channels, micropores of variable shapes, sizes and pore spaces.

For a detailed analysis, diatomite samples were studied using energy dispersive X-ray spectroscopy, which provides information on the qualitative and quantitative composition of the sample (Fig. 2).

A diatomite sample was also investigated by one of the most effective spectroscopic methods for analyzing surface chemistry, such as infrared spectroscopy. The transmission spectra of natural diatomite (Fig. 3) are characterized by absorption bands at 1636,17, 798,00 and 470.18 cm^{-1}, due to deformation vibrations of the Si–O quartz bond.

The absorption bands at 798 cm^{-1}, associated with deformation vibrations of the CO_3^{2-} group, prove the presence of calcite in the sample. The absorption bands of 3697,81 and 3621 cm^{-1} are characteristic of the vibrations of the OH- group of water. Peaks corresponding to Si–OH or Al–OH bonds are characterized by absorption bands at 915–917 cm^{-1} and Si–O–Al and bonds with the Al– octahedral sheet are found at 533 cm^{-1} (Fig. 3).

Further, these two samples were used for water purification as a sorbent and experiments were carried out to determine the degree of removal of Pb^{2+} ions from solutions.

To determine the static sorption properties of sorbents (1M), all experiments were carried out in this way:

1. Preparation of the solution (lead nitrate C = 100 mg/l).

2. The mass of sorbents 1 g, the mixing time t = 5, 30, 120 min.

The adsorption capacity (A) and the degree of extraction (α) of the sorbent are determined by the following formula:

Table 1

Specific surface area of Kazakhstan diatomite and diatomite from the Republic of Iran

	Title		BET
1	Pure diatomaceous earth	Specific surface, sq.m/g	32,222
		Specific pore volume, cubic cm/g	0,017
		The average pore size, nm	1,713
2	Iranian diatomite	Specific surface, sq.m/g	25,221
		Specific pore volume, cubic cm/g	0,015
		The average pore size, nm	1,713

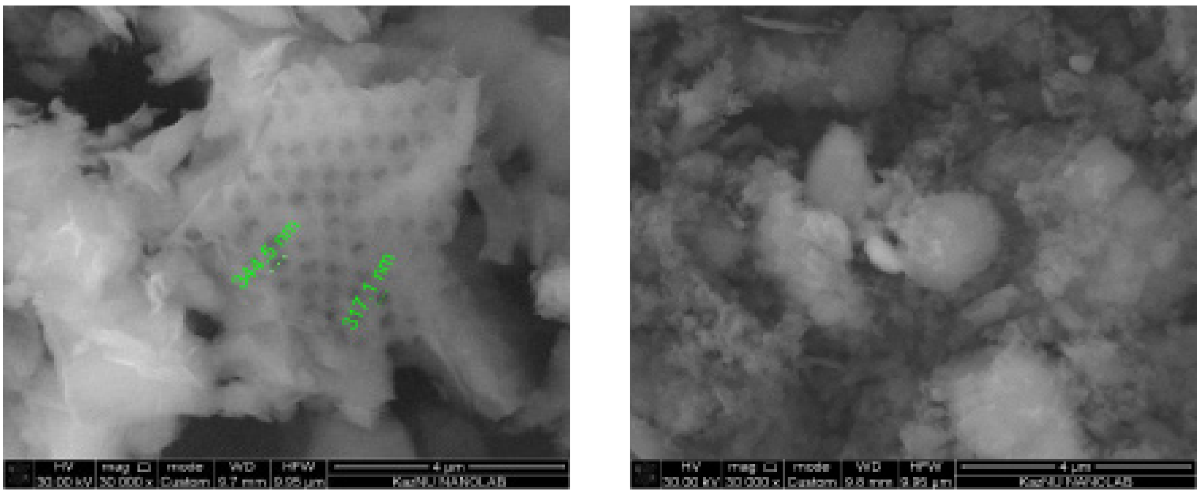
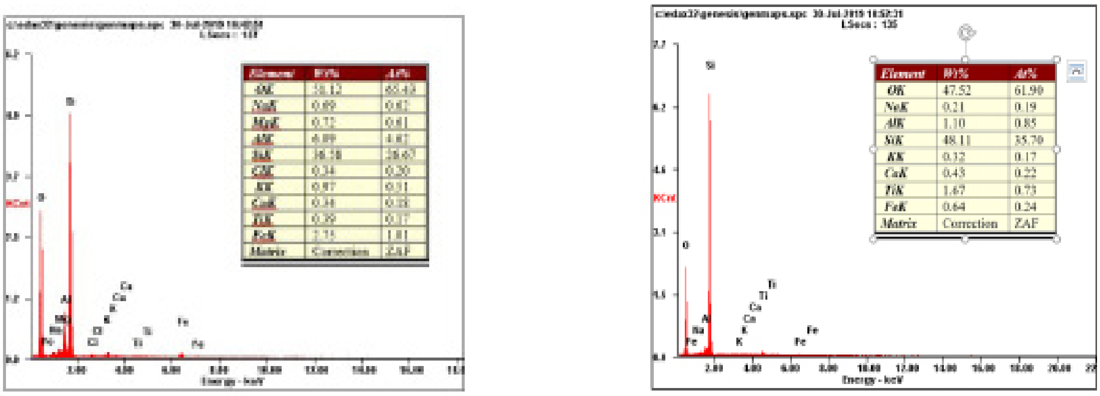


Fig.1. SEM analysis of pure diatomite from different region: (a) Diatomite (Kazakhstan); (b) Iranian diatomite.

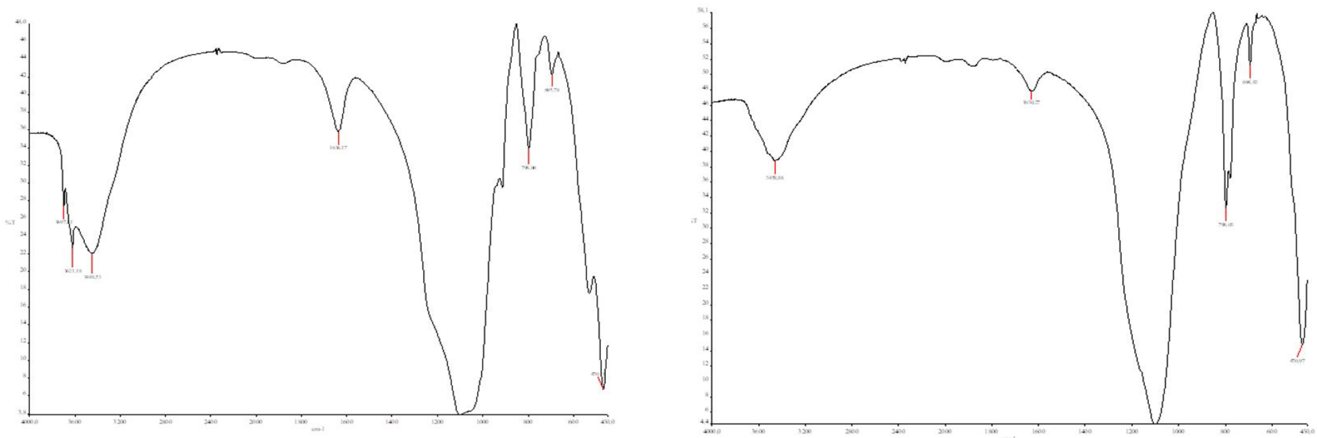
Table 2
Specific surface area of Kazakhstan diatomite and diatomite from the Republic of Iran

Sample	Time, min	Degree of extraction [α], %
Diatomite (KZ)	5	88
	30	98
	120	97
Iranian diatomite	5	63,8752
	30	21,5542
	120	60,0687



(a) (b)

Fig.2. EDAX analysis of pure diatomite from different region: (a) Diatomite (Kazakhstan); (b) Iranian diatomite.



(a) (b)

Fig. 3. IR analysis of pure diatomite from different region: a) Diatomite (Kazakhstan); b) Iranian diatomite.

$$A = (C_0 - C)\, V_{sol}/m_{sorb} \quad (1)$$

$$\alpha\,(\%) = (C_0 - C)\cdot 100/C_0 \quad (2)$$

where, C_0, C – respectively, the initial and equilibrium concentration of metal ions, mg/l; V_{sol} – solution volume, l; m_{sorb} – mass of the sorbent, g; A – adsorption capacity, mg/g; α – degree of extraction, %.

Specific surface area of samples from two region presented in Table 2.

Thus, the maximum degree of removal of Pb^{2+} ions from solutions with a concentration of 100 mg/l for diatomite is 98 and 97%, with a mixing time of 5, 30 and 120 min, respectively.

The A_{max} value for pure Kazakhstan diatomite is 9.55 mg/g, Iranian diatomite is 8.23 mg/g, which proves the preference for adsorption of Pb^{2+} ions on the surface of pure Kazakhstan diatomite. Thus, according to the results of studying the adsorption isotherm, the adsorption of Pb^{2+} ions on the surface of pure Kazakhstan diatomite proceeds in the best way.

Based on the obtained results, it can be argued that pure diatomite from Mugaldzhar region of the Republic of Kazakhstan is a universal adsorbent for many metal ions.

Conclusion

It was chosen pure diatomite samples from two regions: Kazakhstan and Iran. According to the obtained results, it was established that pure diatomite from Kazakhstan is a universal adsorbent for Pb^{2+} ions, degree of extraction is 98 and 97%.

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Благодарность

Работа выполнена по проекту № AP05133836 «Получение наноструктурированных материалов на основе диатомита для очистки воды».

Использование чистого диатомита для сорбции тяжелых металлических ионов

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АННОТАЦИЯ

В данной статье представлены результаты по очистке воды на основе диатомитовых сорбентов. Результаты исследования образцов диатомита из двух различных регионов показывают, что адсорбционная емкость, удельная поверхность и степень извлечения сорбента Республики Казахстан выше, чем у иранского диатомита.

Ключевые слова: диатомит, сорбция, сорбенты, ионы металлов.

Ауыр металл иондарын сіңіру үшін таза диатомитті қолдану

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АҢДАТПА

Ұсынылып отырған мақалада диатомит негізді сорбентермен су тазалау бойынша нәтижелер келтірілген. Әртүрлі екі аймақтың диатомит үлгілерін зерттеу нәтижелері, Қазақстан Республикасының сорбентінің адсорбциялық сиымдылығы, беттік ауданы мен сорбенттің бөліп алу дәрежесі, Иран диатомитіне қарағанда жоғары екендігін көрсетті.

Кілт сөздер: диатомит, сіңіру, сорбенттер, металл иондары.