Study of Modified Peanut Peel Sorption Properties Relative to Fe (III) Ions

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Abstract. In this paper, we consider the possibility of extracting Fe³⁺ ions from aqueous media with native and modified peanut peel. Peanut peel is an unclaimed waste generated after extracting peanut kernels and at present, it is directed to burning. Meanwhile, the peanut peel is a cellulose-containing material with a branched pore system and a large specific surface, which determines the prerequisites for using it as a sorption material in water treatment processes. Before use, the peanut peel (PP) was crushed and dispersed using a standard set of sieves to obtain fractions of particles of various compositions. Adsorption isotherms are plotted and the maximum isotherm (A_{max}) was determined, which was 1.52 mmol/g or 85.7 mg/g for the initial material and 1.6 mmol/g or 96.0 mg/g for burnt at 350 °C.

1. Introduction

Recently, the hydro chemical regimes of surface water bodies have been significantly affected by anthropogenic activities. This activity is manifested in the discharge of contaminated or insufficiently treated sewage into the water bodies. The consequence of this is the increasing global pollution of the hydrosphere. The phenomenon is especially acute in developing countries, for example in Syria. In such countries, despite the strategy of sustainable development adopted in many countries of the world, which envisages the rational use of natural (including water) resources, the concept of rational nature management is not fully implemented.

Unfortunately, developing countries, in pursuing their industrialization policies, not only adopted the positive experience of Western countries in solving economic problems, but also repeated their environmental miscalculations. The only resources they possessed except cheap labor were natural. Their development and intensive use also provided the basis for economic development. The consequences of this are manifested in the depletion of natural resources, undermining ecosystem resilience, disturbing water balance, soil degradation, reducing biodiversity, and deforestation [1].

One of the possible ways to reduce the negative anthropogenic impact on water bodies is the effective treatment and post-treatment of sewage. For this purpose, a wide range of diverse methods is used, among which sorption is one of the most effective and selective ways.

Adsorption is widely used for sewage treatment containing various pollutants [2-4].

It should be noted that sorption processes are ubiquitous in natural water systems, providing self-purification of water bodies. Table 1 shows typical sorption interactions in the hydrosphere [5].
Table 1. Examples of natural sorption systems.

| Natural solid materials as sorbents | Liquid phase in contact with solid one |
|------------------------------------|---------------------------------------|
| River and Lake deposits            | Surface Waters                        |
| Suspended Substances in Ground and |                                       |
| Surface Waters                     | Ground waters                         |
| Soil                               | Capillary water, infiltrate           |

The adsorption process involves the concentration of pollutants on the surface of the sorption material due to physical and / or chemical forces. Adsorption is influenced by many parameters, such as the nature of the substances and the sorbent, the presence and size of pores, the presence of active centers on the surface of the sorption material, the presence of competing substances in the solution, etc. [6-7].

Despite the high cleaning efficiency for many pollutants, industrial activated carbons are quite expensive, so it is often preferable to use other sorption materials, for example on the base of industrial or agricultural wastes.

In the literature there is evidence of numerous developments in this direction. So, in agro-industrialized regions, the use of large-scale agricultural waste, such as saturation sediment, is promising [8]. Studies on the modification and the possibility of using this material for water treatment have shown its effectiveness for sewage of various compositions.

Traditionally, high rates of cleaning efficiency are demonstrated by sorption materials obtained from plant waste, which is due to their chemical structure. The presence of cellulose and related substances suggests high sorption properties of materials formed after physical, chemical, or multi-stage modification [9].

At the same time, many researchers note that, despite the apparent similarity, sorption materials obtained from various plant components can have noticeable differences in sorption efficiency, capacity, and affinity for chemical compounds [10, 11].

In this work, we studied the possibility of extracting Fe\(^{3+}\) ions from aquatic medium with ground peanut peel.

2. Materials and methods

We used model solutions containing Fe\(^{3+}\) ions with a concentration of up to 1000 mg/dm\(^3\). Solutions were prepared by dissolving the Fe\(_2\) (SO\(_4\))\(_3\) \times 9H\(_2\)O salt in distilled water.

The particle size distribution of ground peanut peel is determined by sieving using a standard set of sieves. According to this method, the share of each fraction (%) is determined by weighing the individual fractions of particles passing through sieves with a known mesh size.

The elemental composition of the studied sorption materials is determined by the method of energy dispersive analysis (EDAH analyzer), combined with the Quanta 2003 D ion-electron microscope [12-14]. The energy-dispersive analyzer has a Si-Li Sapphire X-ray detector with a manganese resolution of 130 eV. The ultra-thin input window of the detector is made of a polymer film, which makes it possible to determine the chemical composition of materials in the range of elements from Be to U.

Bulk density was determined according to GOST R "Standard method of determining the bulk density of activated carbon" [15]. The bulk density was determined by the free fall of particles into a graduated cylinder and by determining the mass of a given volume (V). According to the standard, depending on the nominal particle size, a graduated cylinder with a capacity of 100 cm\(^3\) is chosen. The inner diameter of the cylinder must be at least 10 values of the average particle size. When filling the cylinder, air entry is avoided. Level of the layer top is made by tapping lightly on the cylinder wall. The contents of the cylinder are weighed with accuracy to 0.1 g. The bulk density \(\rho_{\text{bulk}}, \text{g/cm}^3\), is calculated according to the following formula (1):

\[
\rho_{\text{bulk}} = \frac{M}{V} \tag{1}
\]

where M is the mass of sorption material, g.
V is the sample volume of the sorption material, cm$^3$.

To build sorption isotherms in 14 flat-bottomed flasks with a capacity of 250 cm$^3$, sample weights of the studied sorption materials (peanut peel of the original PP$_i$ and burnt at 350 °C - PP$_{350}$) weighing 1 g.

Then, 200 cm$^3$ of model solutions containing Fe$^{3+}$ ions in a concentration of 10 mg / dm$^3$ (0.179 mmol/dm$^3$) to 3000 mg / dm$^3$ (53.57 mmol/dm$^3$) are poured into the flasks. Model solutions were prepared by dissolving the Fe$_2$ (SO$_4$)$_3 \times 9$H$_2$O compound, while taking sample weights, the presence of crystallization water was taken into account.

Flasks with sorption material and model solutions were tightly closed with stoppers and shaken vigorously for 6 hours. Then, the sorption material was filtered by a paper filter, and the residual concentrations of Fe$^{3+}$ ions were determined in the filtrates by the photo colorimetric method in accordance with the standard procedure [16].

The amount of Fe$^{3+}$ ions of 1 g sorption material were calculated by the formula (2):

$$ A = \frac{(C_0 - C_p) \times 200}{1 \times 1000} $$

where $C_0$ is the initial concentration of Fe$^{3+}$ ions, mol / dm$^3$;

$C_p$ - final (equilibrium) concentration of Fe$^{3+}$ ions, mol / dm$^3$;

200 - volume of model solution, cm$^3$;

1 - weight of sorption material, g;

1000 - transition from cm$^3$ to dm$^3$.

3. Results and discussion

According to the obtained equilibrium concentrations of Fe$^{3+}$ ions in the filters and the calculated values of the sorption capacity (A), adsorption isotherms are constructed (Fig. 1.)

Figure 1. Adsorption isotherms of Fe$^{3+}$ mol / dm$^3$ ions with ground peanut peel of the original (1) and burnt at 350 °C (2).

It was found that the maximum sorption capacity on Fe$^{3+}$ ions in a neutral medium of ground peanut peel is 85.1 mg/g (1.52 mmol/g) for PP$_i$ and 96.0 mg / g (1.6 mmol/g) for PP$_{350}$.

The obtained adsorption isotherms belong to type I adsorption isotherms according to the BET classification and describe the monomolecular adsorption of Fe$^{3+}$ ions on the test material.

To describe the mechanism of the process and determine its nature, the adsorption isotherms were processed in the framework of the monomolecular models of Langmuir, Freundlich, Temkin according to equations 3-5.

$$ \frac{1}{A} = \frac{1}{A_\infty} + \frac{1}{K_L + A_\infty + C_p} $$

Langmuir Equation

$$ \log A = \log K_F + n \log C_p $$

Freundlich Equation
The Temkin Equation is given by:

\[ A = \frac{R \times T}{b_{TE}} + \frac{R \times T}{b_{TE}} \times \ln C_p \]  

(5)

The results of adsorption isotherms processing are presented in Figure 1 in the framework of the Langmuir, Freundlich, and Temkin models shown in Figures 2-4.

**Figure 2.** Dependence \(1/A = f\left(\frac{1}{C_p}\right)\) for the adsorption of Fe\(^{3+}\) ions by peanut peel: 1- initial and 2- burnt at a temperature of 350 °C.

**Figure 3.** Dependence \(\log A = f(\log C_p)\) of Fe\(^{3+}\) ion adsorption processes by peanut peel: 1- initial and 2- burnt at a temperature of 350 °C.

**Figure 4.** Dependence \(A = f(\ln C_p)\) of Fe\(^{3+}\) ion adsorption processes by peanut peel: 1- initial and 2- burnt at a temperature of 350 °C.
According to the obtained data of dependences within the framework of monomolecular models, it follows that the adsorption isotherms are best described by the equations.

To confirm the sorption mechanism and the stage that limits the rate of the sorption process, we studied the sorption kinetics of Fe$^{3+}$ ions by the initial and burnt peanut peel; the concentration of Fe$^{3+}$ ions in model solutions was 1000 mg/dm$^3$.

Sample weights of the studied sorption materials (initial and burnt peanut peel weighing 1 g each) were placed into flat bottom flasks with a capacity of 250 cm$^3$. Then the flasks were closed with lids and shaken on an automatic shaker for specified periods of time - from 20 to 160 minutes.

At the end of the shaking, the contents of the flasks were filtered through a paper filter, and the residual concentration of Fe$^{3+}$ ions was determined in the filtrates. According to the obtained results the dependences of the residual concentration of Fe$^{3+}$ ions on the shaking time were plotted. The concentration of Fe$^{3+}$ ions in the solution decreases the most intensively in the first 60 minutes, then the rate of decrease in the concentration of Fe$^{3+}$ ions decreases. This is probably due to the fact that physical adsorption occurs in the initial period of the process (the wetting area), and then the chemisorption stage (binding area) follows.

4. Conclusion

Under static conditions, the adsorption properties of ground peanut peel in the initial and thermally modified form (roasting at a temperature of 350 °C) due to Fe$^{3+}$ ions were studied. According to the obtained values of initial (C$_i$) and equilibrium (C$_p$) concentrations, the values of sorption capacities (A) of sorption materials were calculated and sorption isotherms were plotted:

\[ A = f (C_p) \]

the processing of which using the Langmuir, Freundlich, and Temkin models, the equations of adsorption processes and the approximations ($R^2$) coefficients were determined. It has been established that the adsorption processes of Fe$^{3+}$ ions by the initial and thermally modified peanut peel are most accurately described by Langmuir models ($R^2 = 0.988$; $R^2 = 0.979$).

It was shown that the concentration of Fe$^{3+}$ ions in the solution decreases the most intensively in the first 60 minutes of processing the solution with sorption material, then the decrease in concentration slows down.

References

[1] The problem of fresh water The global context of Russian politics 2011 (Moscow: MGIMO-University)
[2] Filonik A O 1999 Environment and development in the Arab world Digest of articles pp 24-46
[3] Kaisi A, Yasser M, Mahrousheh Y 2005 Non-conventional water use: WASAMED project Bari: CIHEAM/EU DG Research pp 251-264
[4] Isaev V A 1999 Environment and development in the Arab world Digest of articles pp 102-116
[5] Scientific Information Center of the Interstate Coordination Water Commission of Central Asia of the Middle East River Part 1 Euphrates, Orontes 2015 Information collection 42 (Tashkent)
[6] Shahin Bashar Suleiman 2015 Bulletin MGOU. Series: Natural Sciences 1 pp 70-77
[7] Spirin M N, Sverguzova S V 2014 Bulletin of BSTU named after V. G. Shukhov 5 pp 187-191
[8] Galimova R Z et al. 2016 Bulletin of BSTU named after V.G. Shukhov 10 pp 179-184
[9] Saponova Zh A, Sverguzova S V 2017 Palmarium Academic Publishing 288 p
[10] Sverguzova S V, Saponova Zh A, Svyatchenko AV, Otiti T 2018 Building Materials and Products vol 1 1 pp 4 – 11
[11] Saponova Zh et al 2018 IOP Conf. Series: Materials Science and Engineering 365 022058
[12] Saponova Zh A, Sverguzova S V, Fomina E V 2017 Advances in Engineering Research vol 133 pp 728-733
[13] Svyatchenko A V et al. 2018 Chemical Bulletin vol 1 4 pp 19-30
[14] Scanning electron microscopy and X-ray spectral microanalysis in practical applications 2009 (Moscow: Technosphere)
[15] GOST R 55959-2014 Activated carbon Standard method for determining bulk density Test Methods – Introduction 2014 (Moscow: Standartinform)
[16] GOST 4011-72 2008 Drinking water Methods for measuring the mass concentration of total iron (with Changes 1, 2) Test Methods – Introduction (Moscow: Standartinform)

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