Effect of sodium nitrate salt concentration on the efficiency of extraction of iron (III) ions by electroflotosorption method

Pokhvalitova Anastasia Aleksandrovna

Undergraduate

Gaydukova Anastasia Mikhailovna

Candidate of Chemical Sciences, Associate Professor

D. Mendeleev University of Chemical Technology of Russia

Abstract. In this work, experimental studies of the sorption of Fe^{3+} ions on a powder sorbent of the "OU-A" brand in a static mode from sodium nitrate solutions with a concentration of 1 - 50 g/l have been carried out. To extract the spent carbon sorbent from aqueous solutions of $NaNO_3$, the electroflotation method was used, for the intensification of which an appropriate flocculant was used. The effect of increased concentration of sodium nitrate on the efficiency of electroflotation extraction of powdered coal from solution is considered. The possibility and prospects of using the electroflotosorption method for purifying a sodium nitrate solution with a concentration of up to 50 g/l from iron (III) ions is shown.

Keywords: electroflotation, sorption, carbon powder material, flocculant.

Introduction

The environmental problem related to water pollution by technological waste has been in the focus of human attention for many years, since the wastewater of chemical plants has a complex composition and contains heavy metals, toxic organic compounds, as well as high concentrations of suspended and dissolved solids. Waste aqueous solutions with high salt content are given special attention, since at present there are a large number of industrial enterprises that generate huge amounts of liquid waste with high salt concentrations. Highly concentrated salt solutions are widely used in electroplating industries, where they are part of electrolytes for the application of various metal coatings [1-2]. As a result of the accumulation of impurities in the working baths and, as a consequence, disruption of their performance, waste concentrated solutions are discharged. A significant amount of wastewater with a high salt content is also formed after pickling and degreasing of coatings. In this regard, the search for the most expedient method of wastewater treatment is a difficult task. Currently, most often, the purification of aqueous solutions with a high salt content is carried out by the method of ion exchange, in which both inorganic ion-exchange materials and organic ion-exchange resins can be used as ion exchangers [3-5]. The ion exchange resins used in this method are easily regenerated, but their regeneration

requires a large consumption of acids and alkalis, which leads to high economic costs [6]. Also, in [2] it was noted that as a result of ion exchange, a large amount of sediment is formed, which must be disposed of.

In this work, a combined method of purification of aqueous solutions of sodium nitrate salts is considered, including sorption on powdered activated carbon (AC) in a static mode, followed by extraction of the spent sorbent during electroflotation treatment. The adsorption technology of wastewater treatment is popular due to its simplicity, low cost and high efficiency in the separation of chemical compounds [7-8]. A universal sorbent is activated carbons, which have surface functional groups, a high specific surface area (1000–1300 m^2/g), and a porous structure that provides selective sorption of molecules [9]. Due to these features, they are able to sorb organic and inorganic substances of various natures on themselves, which makes carbon sorbents practically indispensable for wastewater treatment.

By absorbing various harmful and toxic chemical compounds from solutions on its surface, the carbon material becomes hazardous to the environment, but since the size of powdered coals is very small, its extraction from aqueous solutions is difficult. The electroflotation method of cleaning allows you to quickly and efficiently clean solutions with high salt content from suspended solids, organic and inorganic impurities.

Research methodology

The object of research is coal of the "OU-A" grade, which is made on the basis of birch charcoal. Sorption tests were carried out in a static mode with continuous stirring of a solution containing Fe^{3+} and 1;5;10 and 50 g/l $NaNO_3$, with a sorbent for half an hour. Then the sorbent was separated by settling and filtration, as well as during the electroflotation treatment of the solution.

The amount of sorption (A, mg/g) was determined by the formula (1)

$$A = \frac{(c_0 - c_r) \cdot V}{m} \quad (1)$$

where c_0 – initial concentration, mg/l

c_r – residual concentration of a pollutant in a solution or equilibrium concentration, mg/l

V – volume of the treated solution, l

m – sorbent weight, g.

In the experiments, to increase the efficiency of the process, a nonionic flocculant of the Superfloc N-300 series with a concentration of 5 mg/l was used.

Studies of the electroflotation process of extracting suspended solids were carried out in a laboratory setup, the scheme and principle of operation of which are described in detail in [10].

The efficiency of extracting coal particles from solution was estimated by the formula (2):

$$\alpha_{\text{ef}} = \frac{c_0 - c_{coc}}{c_0} \cdot 100\% \quad (2)$$

where, c_0 – initial concentration, mg/l

c_{con} – residual concentration of coal in solution, mg/l.

The mass concentration of coal was measured by the turbidimetric method using a HI 98703 turbidity meter.

The concentration of Fe^{3+} ions was determined photometrically in the presence of sulfosalicylic acid. The optical density of the solutions was measured on an SF-2000 spectrophotometer at a wavelength of 500 nm.

Results and discussions

Activated carbons, due to their porous surface and the presence of functional groups, can participate in both physical and chemical adsorption of various substances. The type of adsorption and its value are greatly influenced by the salt anions present in the aqueous solution, as well as the concentration of this salt. Experimental data were obtained showing the effect of the concentration of sodium nitrate salt on the sorption capacity of the sorbent during the extraction of Fe^{3+} ions from the solution (figure 1).
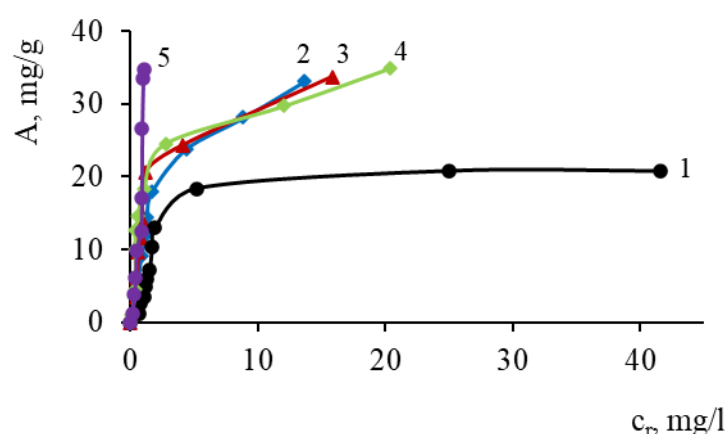

Figure 1 - Isotherms of adsorption of iron (III) ions on a powder carbon sorbent from water (1), 1 g/l NaNO₃ (2), 5 g/l NaNO₃ (3), 10 g/l NaNO₃(4), 50 g/l NaNO₃ (5)

pH = 2,5

From the data presented in the figure, it can be seen that an increase in the concentration of sodium nitrate in an aqueous solution increases the amount of adsorption of the carbon material. An increase in the concentration of the studied salt to 5 and 10 g/l increases the sorption capacity of activated carbon at equilibrium concentrations of Fe^{3+} ions <11 mg/l with a further increase in the concentration of Fe^{3+} in the solution, a slight decrease in the sorption capacity of coal is observed. With an increase in the salt concentration to 50 g/l the adsorption isotherm shape can be attributed to the H type according to the Giels classification, while

complete saturation of the adsorbent is not observed, which indicates that the use of a powder sorbent is promising for the extraction of Fe^{3+} ions from nitrate solutions with increased salinity.

Further extraction of the spent sorbent from solutions of sodium nitrate salts was carried out by the electroflotation method with preliminary correction of the pH values of the medium to 4 and 7 units (table 1). It is known from literary sources that increased salt content complicates the electroflotation process, since a high electrolyte concentration suppresses the hydrogen evolution reaction due to the reduction of nitrate ions. So, under these conditions, the gas saturation of the aqueous solution with hydrogen decreases.

Table 1 – Influence of sodium nitrate concentration and pH of the medium on the electroflotation process of extracting carbon material "OU-A" in the presence of Fe^{3+}

c (NaNO₃), g/l c(AC), g/l	Recovery rate "OU-A" (α_{ef}), %			
	pH = 4		pH = 7	
	0.2	0.5	0.2	0.5
1	90	97	97	98
5	90	97	95	97
10	90	97	94	97
50	90	96	94	95

Experimental conditions: τ=20 minutes; i_v = 0,2 A/l; $c(Fe^{3+})$ = 25 mg/l; $c_{floc.(N-300)}$=5 mg/l

It can be seen from the obtained experimental data that an increase in the concentration of the background sodium nitrate salt in an acidic and neutral medium in the presence of Fe^{3+} ions in an aqueous solution does not affect the electroflotation process of extracting carbon material. It can be assumed that this is due to a change in the surface properties of the dispersed phase due to a high concentration of nitrate ions in an aqueous solution, which has a positive effect on the extraction of the carbon sorbent.

It should be noted that the added nonionic flocculant promotes the enlargement of particles and the purification of the aqueous solution both from the carbon sorbent and from the forming insoluble iron (III) hydroxide in the process of adjusting the pH of the solution.

During the experiment, it was found that the residual concentration of Fe^{3+} ions after electroflotation treatment of a solution containing 50 g/l of sodium nitrate at pH = 7 in the

presence of 500 mg/l of activated carbon was 0.123 mg/l, which corresponds to the MPC for iron (III).

Conclusion

As a result of the performed experimental studies, it was found that an increase in the concentration of sodium nitrate affects the adsorption mechanism and the sorption capacity of iron (III) ions. The adsorption isotherm with an increase in the concentration of sodium nitrate to 50 mg/l indicates the occurrence of chemisorption of iron (III) ions, when the adsorption is accompanied by the formation of a chemical compound. It was found that an increase in the salt concentration does not reduce the efficiency of the electroflotation process of extracting the spent powder sorbent, while the residual concentration of iron (III) ions in a neutral medium does not exceed the permissible MPC standards.

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