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ADSORPTION OF Sr^{2+} IONS FROM AQUEOUS SOLUTIONS ON THE ACTIVATED CARBON CAN-7 UNDER DYNAMIC CONDITIONS

Mihai Ciobanu, Tudor Lupascu, Tatiana Mitina, Igor Povar

Institute of Chemistry, 3 Academiei Street, MD2028, Chisinau, ipovar@yahoo.ca, Republic of Moldova

Abstract

In the paper the eliminating strontium ions from groundwater by using the CAN-7 activated carbon under dynamic conditions has been studied. The activated carbon CAN-7 is obtained by the chemical method, through the treatment with ortho-phosphoric acid at distinct temperatures. It has been proved that by the reduction of the filtration rate of the solution containing strontium ions through the adsorbent column, the strontium ion adsorption is increased. The adsorption of strontium ions from aqueous solutions on the CAN-7 activated carbon has been measured at different lengths of working layer of the adsorbent column and at different filtration rates of the solution. The length of working layer of the column with CAN-7 has been determined as a function of the initial concentration of strontium ions and filtration rates. The activated carbon CAN-7 with adsorbed strontium ions is completely regenerated by 0.36% of hydrochloric acid. The obtained results for the process of adsorption of strontium ions from aqueous solutions on the CAN-7 activated carbon under dynamic conditions has demonstrated the option of removing this pollutant from the deep waters.

Keywords: *activated carbon, adsorption, aqueous solution, chemical activation, dynamic conditions, nut shells*

Introduction

Heavy metals penetrate the life form through water, air and food. If their amount exceeds the maximum admissible concentration, then there are health problems in the human body. Most heavy metal ions interact with N, S, O and P electron donors from the chemical structure of proteins in living organisms by forming coordinating compounds. The initiated reactions take place in the cell membrane and are followed by the penetration of toxic substances into the cells, which in turn lead to their physiological modification.

Presently there are a series of papers on the adsorption of Sr^{2+} ions from aqueous solutions on different types of adsorbents (Chegrouche et al 2009, Hasany & Chandhary1981, Mitina et al 2015, Moon et al 2011, Shawabkeh et al 2002,Wang et al 2009,Yavari et al 2010, Zhang et al 2004). Scientific studies on the study of adsorption of strontium ions from solutions in dynamic conditions are limited (Mohamed-Ibrahim et al 2011, Yuko et al 2014).

The purpose of this paper is to evaluate the possibility of removing strontium ions from groundwater by using the CAN-7 activated carbon under dynamic conditions. The use of CAN-7 activated carbon under static conditions previously demonstrated a good adsorption capacity compared to other modified activated carbons, obtained

from the same raw material (nut shells), but by using a physicochemical method (Ciobanu et al 2016). The activated carbon CAN-7 was obtained by the chemical method, through the treatment with ortho-phosphoric acid at distinct temperatures.

Materials and Methods

The CAN-7 activated carbon was obtained from nut shells by treatment with ortho-phosphoric acid at 80°C and subsequent activation at 460°C. The activated carbon fraction studied was 0.8-1.0 mm. As adsorbent, strontium nitrate, pure for analysis, was used. The adsorption isotherms were determined at various concentrations of strontium ions in solution, using the same mass of activated carbon at 20°C. The equilibrium concentrations of strontium ions in solutions were determined on the AAS-1 spectrophotometer. One of the efficient methods of removing Sr^{2+} ions from deep water is the adsorption method using modified activated carbon. The study of the process of adsorption (*a*) of strontium ions from aqueous solutions on the CAN-7 activated carbon under static conditions proved the possibility of removing this pollutant from deep waters (Figure 1) (Ciobanu et al 2016).

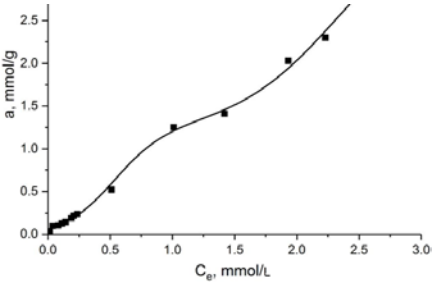

Figure 1. Adsorption isotherm (adsorption *a* versus equilibrium concentration C_e) of Sr^{2+}ions from aqueous solutions on the CAN-7 activated carbon under static conditions, $t = 20^0$C.

Figure 1 demonstrates that the activated carbon CAN-7, obtained from nut shells by chemical activation with ortho-phosphoric acid, can bind strontium ions in much greater amounts than it can be present in deep waters. As an example, in the artesian fountain of the Mandra village of the Calarasi district the concentration of strontium ions is 48 mg/L, the maximum admissible concentration being 7 mg/L. It is easy to assume that the value of adsorption of strontium ions on this adsorbent will be higher under dynamic conditions, obviously at reasonable filter rates.

Figure 2 shows the curve of the Sr^{2+} ions adsorption dynamics from aqueous solutions on the fractionated CAN-7 activated carbon (2.0-3.0 mm) at a filtration rate of 6.7 m/hr. The initial concentration of the solution was 100 mg/L. The adsorption column had a length of 91 cm and its diameter was 1.8 cm. From the data presented in Figure 2, it can be seen that at a filtration rate of 6.7 m/hr, the adsorbent column practically does not work, since the contact time of the activated carbon granules and Sr^{2+} ions is too low.

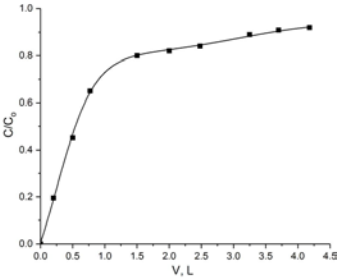

Figure 2. Dynamics of the adsorption of Sr^{2+} ions from aqueous solutions on the CAN-7 activated carbon. Rate of filtration is 6.7 m/hr, the filtration volume V_{fil} is in L.

The decrease of the filtration rate to 5.75 m/hr (Figure 3) demonstrates a modification of the curve allure of the adsorption dynamics, but without yielding results that could be used for practical removal of Sr^{2+} ions.

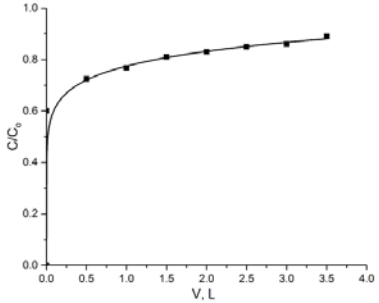

Figure 3. Dynamics of adsorption of Sr^{2+} ions from aqueous solutions on the CAN-7 activated carbon. Rate of filtration V_{fil} is 5.75m/hr.

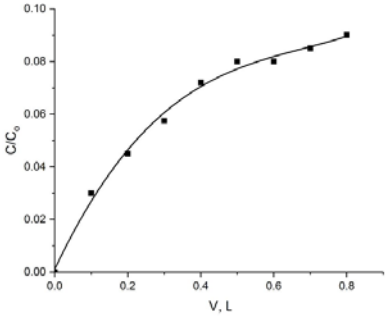

Figure 4. Adsorption isotherm of Sr^{2+} ions from aqueous solutions on the CAN-7 activated carbon under the dynamic conditions. Rate of filtration V_{fil} is 1.9m/hr.

At a filtration rate V_{fil} of 1.9 m/hr (Figure 4) there is a significant change in the curve of the adsorption dynamics of the strontium ion on the CAN-7 activated carbons at relatively low values of the filtrate volumes.

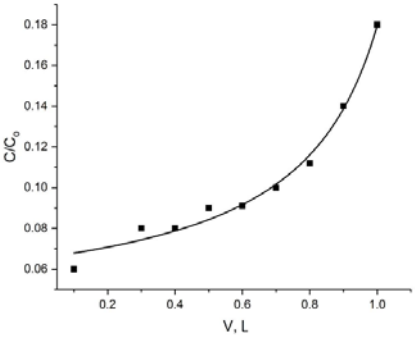

Figure 5. Adsorption isotherm of Sr^{2+} ions from aqueous solution on the CAN-7 activated carbon under dynamic conditions. The filtering rate V_{fil} is 0.95m/hr.

Figure 5 shows an increase in the adsorption value compared to Figure 4, the filtration rate being 1.9 m/hr. Indeed, from Figure 5 at filtrate volume of 0.1L, C/C_o is of 0.06, and from Figure 4 at the same volume, C/C_o is equal to 0.03.
The measured adsorption of strontium ions from aqueous solutions on the CAN-7 activated carbon as afunction of the length of adsorbent layer in the column (L) is shown in Figure 6 and Figure 7.

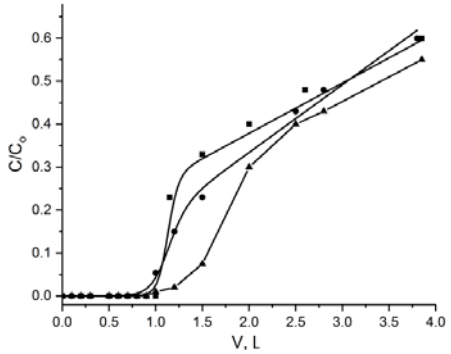

Figure 6. Adsorption isotherms of Sr^{2+} ions from aqueous solutions on the CAN-7 activated carbon under dynamic conditions. The filtering rate is 0.85m/hr. Length of the adsorbent layer, l: 80mm (■), 130mm (●), 190 mm (▲).

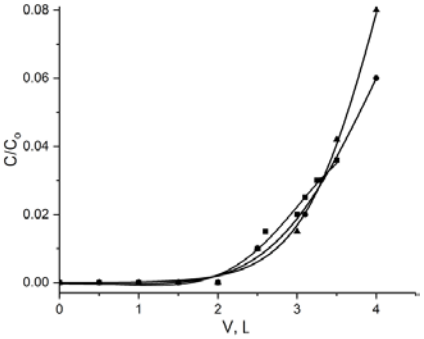

Figure 7. Adsorption isotherms of Sr^{2+} ions from aqueous solutions on the CAN-7 activated carbon under dynamic conditions. The filtering rate is 0.85m/hr. Length of the adsorbent layer, *L*: 250 mm (■), 300 mm (●), 360 mm (▲).

Based on the data from Figure 6 and Figure 7 (Sr^{2+} ion permeation concentrations), Figure 8 shows the dependence of the loss of the directional effect of the adsorption layer (τ) on the length of the adsorbent layer (*L*, mm).

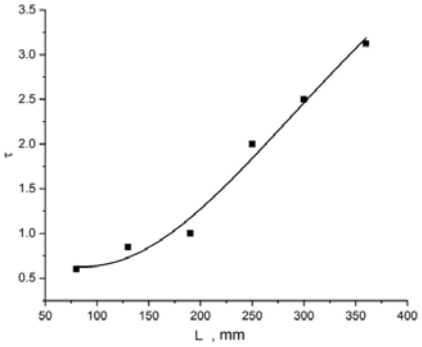

Figure 8. The dependence of the loss of the directional effect of the adsorption layer (τ) on the length of the adsorbent layer (*L*).

From the data presented in Figure 8, the working length layer of column with the CAN-7 activated carbon (l_o), which is equal to 185mm, is determined.
Further, the column containing CAN-7with strontium ions adsorbed was subjected to the regeneration process with 0.36% hydrochloric acid. The acid solution was filtered through a column with the same filtration rate of 0.85 m/hr. The obtained data are shown in Figure 9. This figure shows the complete removal of strontium ions from the porous structure of the adsorbent after filtration of 2 liters of 0.36% hydrochloric acid. Thus, the CAN-7 activated carbon was completely regenerated. Consequently, strontium ions were adsorbed on the inner surface of activated carbon and thus it was possible its removal with acid. Only from the matrix of the activated carbon strontium could not be washed. There is no need to determine the concentration of strontium directly in the activated carbon.

Results and Discussion

It has been confirmed that by the reduction of the filtration rate of the solution containing strontium ions through the adsorbent column, the strontium ion adsorption value is increased. In the adsorbent process, under dynamic conditions, the adsorption capacity is lower than under static conditions. In this case the adsorbent layer is characterized by the dynamic activity (a_d) which is always smaller than the static activity (a_s). The degree of adsorption capacity of the adsorbent (a_d/a_s) is usually between 0.8-0.9.

It is obvious that the working time of column containing activated carbons depends on the initial concentration of strontium ions in the solution to be filtered, as well as on its filtration rate.

The contact time τ of the solution containing strontium ions with the adsorbent granules depends on the size of the column and the filtration rate $V_{fil}$of the solution filtered through it:

$$\tau = V_{ads.}/V_{fil.} \quad (1)$$

where $V_{ads.}$ is the adsorbent volume.

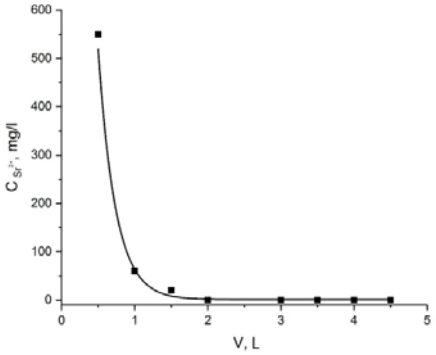

Figure 9. Dynamics of desorption of Sr^{2+} ions from the CAN-7 activated carbon. The filtration rate of 0.36% hydrochloric acid solution is 0.85 m/hr. Length of the adsorbent layer is 360mm.

The dimensions of the adsorption column: height of the column was 910mm, its thickness was 18mm. By introducing these values in equation (1), for each filtering rate (6.7, 5.75, 1.9, 0.95 m/hr), the contact time of the strontium ions with the adsorbent granules is equal to 2.25, 2.6, 7.9 and 15.8 min respectively.

From the data obtained an increase in the contact time of the strontium ions with the adsorbent granules with the reduction of the filtration rate of the solution through the column was noticed. Obviously, the value of adsorption of strontium ions on the adsorbent will be higher as the contact time of the solution with the adsorbent granules increases.

Conclusions

The study of the process of adsorption of strontium ions from aqueous solutions on the CAN-7 activated carbon under dynamic conditions has demonstrated the option of removing this pollutant from deep waters.

It was found that at the filtering rate 0.85 m/hr of the solution, initially containing 100 mg/L of Sr^{2+}, on the CAN-7 activated carbon, the length of working layer of the column is 185 mm.

The activated carbon CAN-7 with adsorbed strontium ions was completely regenerated with 0.36% hydrochloric acid.

Acknowledgements

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