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ADSORPTION OF STRONTIUM ON DIFFERENT BENTONITES

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ABSTRACT

Three different bentonites with similar cation exchange capacities were investigatedas adsorbents for Sr^{2+}ionsin aqueous solutions.Textural properties of thebentonite samples were determined using low-temperature N_2 physisorption method.Adsorption was carried out with respect to contact time. It was found that adsorption capacity of all adsorbents towards Sr^{2+} ions was similar.It was shown that ion exchange mechanism is the dominant mechanism of Sr^{2+} ions adsorption on the Na-enriched bentonites.Adsorption dynamics obeyed pseudo-second-order kinetics model for all bentonites.

INTRODUCTION

Strontium (Sr) is abundantly present in Earth's crust in the form of minerals: $SrCO_3$, $SrSO_4$ and $Al_2O_3 \cdot SrO \cdot (SiO2)_6 \cdot 4H_2O$. In surface waters strontium originates from weathering of the rocks, or from the discharge of waste water from industries that use strontium compounds. Ionic strontiumisnot toxic in small concentrations, and since its concentration in water is generally low. Beyond four stable Sr isotopes naturally present in soil, there are also artificial, radioactive isotopes ^{89}Sr and ^{90}Sr [1, 2]. These radioactive isotopes occur as waste productsin nuclear power plants and in the reprocessing of nuclear fuels [3]. The disposal of radioactive wastewater from commercial nuclear plants is one of the major problems in nuclear waste management [4]. Similar adsorptive behavior of the radioactive Sr isotopes with the non-radioactive ones enables the investigation of the adsorptive removal of radioactive Sr from aqueous solutions on model systems containing non-radioactive isotopes.

The present work wasfocusedon the removal of strontium ions (Sr^{2+} ions) from aqueous solutions using three different sodium enriched bentonites with similar cation exchange capacities (CEC) but with different specific

surface areas. The adsorption was studied as a function of adsorption time, and the results were interpreted using kinetic models of pseudo-first and pseudo-second order.

EXPERIMENTAL
Three bentonite samples (Texas, Wyoming and Bogovina) were usedas adsorbents. Two bentonites were supplied by the Clay Minerals Society originated from Texas (CEC=71.2) and Wyoming (CEC=71.4). The third one was from domestic Bogovina Coal and Bentonite Mine in Serbia(CEC=67.2). The samples were sieved through 74 μm sieves. Sodium enrichment of thebentonite sampleswas performed using previously reported procedure [5] and the obtained materials based on Wyoming, Texas and Bogovina bentonites were denoted as NaW, NaT and NaB, respectively.
$SrCl_2 \cdot 6H_2O$ was obtained from Carlo Erba and used as received.
Nitrogen physisorption isotherms were determined on a Sorptomatic 1990 Thermo Finnigan instrument at −196 °C and textural parameter values were calculated according to common models [6–8].
Batch-type adsorption experiments were conducted in aqueous solutions in a temperature-controlled water bath shaker (Memmert WNE 14 and SV 1422). The adsorption of Sr^{2+}ions was investigated with respect to contact time. The aliquots were withdrawn from the shaker at regular time intervals and the solution was centrifuged at 17000 rpm for 10 min (Hettich EBA-21). The Sr^{2+} content in the supernatant solutions was determined by inductively coupled plasma optical emission spectrometry (ICP–OES). The ICP–OES measurements were performed using a Thermo Scientific iCAP 6500 Duo ICP instrument (Thermo Fisher Scientific, Cambridge, UK).
All experiments were carried out at T=298,15 K, using the same mass of adsorbent (m_{ads} =20.0 mg) and volume of solution (v=50.0 cm^3).The initial concentration of Sr^{2+} ions was 50 mg dm^{-3}.
The amount of Sr^{2+} adsorbed after time t - q_t (mg g^{-1}), was calculated from the following mass balance relationship:

$$q_t = \frac{(C_0 - C_t)v}{m_{ads}} \quad (1)$$

where: $C_0$and C_t are the initial Sr^{2+}solution concentration (mg dm^{-3}) and the Sr^{2+}concentration after the adsorption time t, respectively. The obtained data were investigated using the pseudo-first and pseudo-second kinetics models.

RESULTS AND DISCUSSION
Low temperature N_2 physisorption measurements resulted in isotherms characteristic for mesoporous materials that contain aggregated planar

particles forming slit shape pores, with the presence of micropores. Selected textural properties parameters are presented in Table 1.

Table 1. Selected textural properties

Sample	S_{BET} [m^2g^{-1}]	$V_{0.98}$ [cm^3g^{-1}]	V_{mes}^{BJH} [$cm^3 g^{-1}$]	S_t [$m^2 g^{-1}$]	$S_{mic}=S_{BET}-S_t$ [$m^2 g^{-1}$]
NaW	50	0,0759	0,0871	31	19
NaT	106	0,2000	0,2101	83	23
NaB	87	0,0853	0,0788	43	44

Where: S_{BET} – specific surface area (Brunauer, Emett, Teller – two parameter plot); $V_{0.98}$ – total pore volume (Gurvitch); V_{mes}^{BJH} mesopore volume (Barett, Joyner, Hallenda), and S_t – specific surface area (t-plot), S_{mic} – micropore specific surface area

All Na-enriched materials exhibited microporosity developed to different extents. While mesoporous surface area increased in the NaW>NaB>NaT sequence, the increase of the surface area of micropores followed the NaW>NaT>NaB sequence. Microporous surface area should be considered as more relevant in the investigated cation exchange process, since it takes place in the interlamellar smectite region.

The effect of contact time on the amount of Sr^{2+} ions adsorbed on bentonitesis presented in Fig. 1.
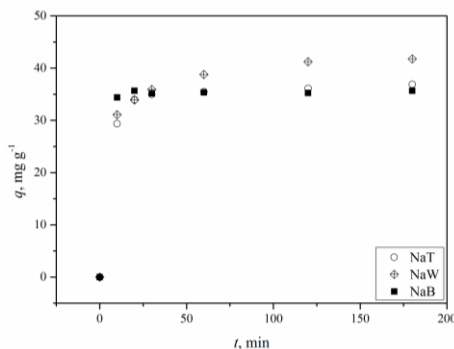

Figure 1. The effect of contact time on the adsorption of Sr^{2+} ions on three different bentonites

For all adsorbents, adsorption rate was initially high and then,it gradually reached plateau. The adsorption capacity of the domestic adsorbent from Bogovina was similar to the capacity of commercial bentonites, independently on the difference in their textural properties. This indicates that the ion exchange mechanism was the dominant mechanism. The pseudo-first order and pseudo-second order kinetics models were tested in the case of Sr^{2+} adsorption on the bentonites. Coefficients of determination (R^2) for

thepseudo-first order model were relatively low, indicating poor correlation of data with the model. On the other hand, R^2 values for the pseudo-second order model were >0.999 for all bentonites. Besides, equilibrium adsorption capacities (q_e), calculated from the equation for the pseudo-second order kinetics model showed good agreement with the experimental values, confirming that the adsorption of Sr^{2+}ions on different bentonites obeyed the pseudo-second order kinetics.

CONCLUSION
In this work, it was shown that the adsorption of Sr^{2+} ions from aqueous solutions on three different Na-enriched bentonites is mainly governed by ion exchange mechanism, since bentonites with similar CEC values and different specific surface areas had similar adsorption capacities. The adsorption dynamics was described well by the pseudo-second-order kinetics model. All investigated adsorbents could be used for the removal of radioactive strontium, considering the fact that it has similar adsorption behavior as the non-radioactive counterpart.

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