

The Removal of Th, Cs and Sr Ions from Solution Using Granulated Pumice Stone*

A. BASSARI, T. AKYÜZ and T. KURTCEBE

Cekmece Nuclear Research and Training Center PK.1 Havalimany, 34831, Istanbul, Turkey.

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Abstract. The removal of Sr, Cs, U and Th ions from aqueous solution by means of natural pumice stone was studied using energy dispersive X-ray fluorescence spectroscopy (EDXRF) as an analytical tool. The results indicate the usefulness of pumice powder and the removal efficiency was found to be in order of Th>Sr>Cs ions, which is altered by the pH of the solution.

Key words. Pumice stone, sorption, XRF.

1. Introduction

Pumice stone is commonly available all over the earth but has not been widely used for the purpose of eliminating heavy metal cations [1]. However, its large surface area, advantageous for sorption, could be investigated and used as an alternative sorbing material to natural zeolites [2,3].

In view of the significant controlling role for the content and distribution of heavy metal pollutants in natural systems the sorption capacity of pumice stone for Sr, Cs, U and Th ions was investigated.

As Th, U, Cs and Sr are of primary interest to scientists, the aim of this work was the study of removal from waters contaminated by ions of the mentioned elements. The study was carried out using model solutions.

2. Experimental

Natural pumice stone obtained from Anatolia (Kars-Turkey) was used in its natural form after being dried at a temperature of 100 °C. It was powdered and sieved to obtain a 100 mesh fraction.

The composition of pumice stone according to EDXRF analysis was: 6.5% Al₂O₃, 57.0% SiO₂, 0.14% P₂O₅, 1.05% K₂O, 32.6% CaO, 0.05% TiO₂, 0.03% MnO and 1.3% Σ FeO+Fe₂O₃.

Analar grade SrCl₂·6H₂O, Th(NO₃)₄·5H₂O, CsCl and UO₂(NO₃)₂·6H₂O from Merck were used for the preparation of stock solutions of the elements.

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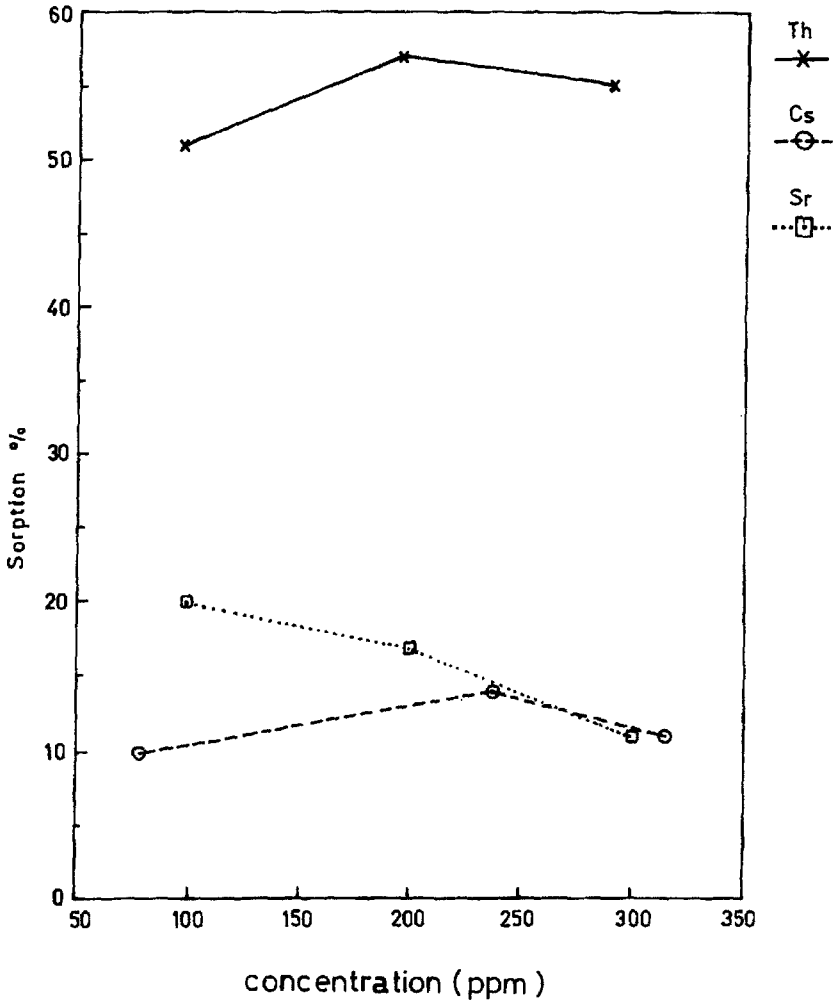


Fig. 1. Th, Sr and Cs sorption onto pumice stone at pH 6.

Pumice powder (200 mg) was added to 50 mL of solution containing 1000 ppm Sr and left for one night at room temperature. The same was done for Cs, Th and U ions. Adjustment of pH to 1, 3, 6, 10 and 14 was done by addition of HCl or NaOH solutions. The samples were filtered and dried for 24 h in an oven at about 85 °C. A 50 mg quantity of cellulose was added to each 100 mg pumice powder and mixed for 5 min. The mixtures were pelletised and stored in a desiccator until analysed. EDXRF analysis was carried out by using a radioisotope excitation X-ray fluorescence analyser. The samples were excited using an Am-241 annular source for 4000 s and a HPGe detector with a resolution of approximately 350 eV FWHM at 5.89 keV was used.

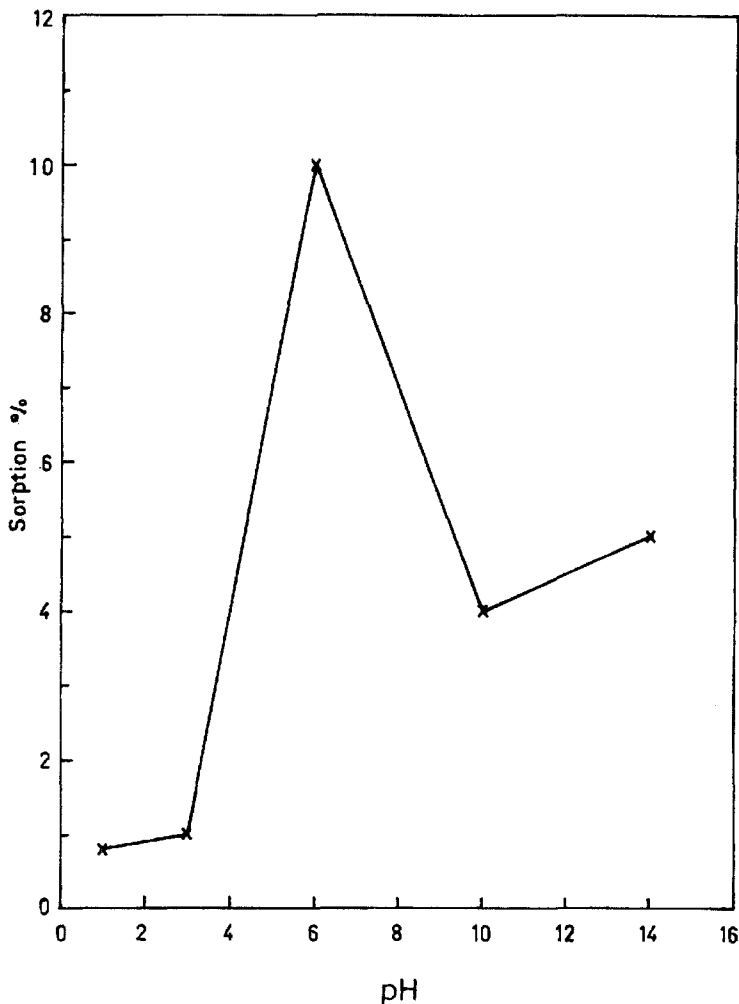


Fig. 2. Sorption of Cs (at 0.97 mg/L concentration) onto pumice stone.

The fundamental parameter technique (FPT) was used to obtain the elemental concentration of the sample. This technique was adopted in this work to minimise the matrix effect in X-ray fluorescence analysis [4].

The intensity of fluorescence measured for a given element is not only dependent on the element's concentration, but also on the mass absorption of the sample for excitation and fluorescence radiation. There are also inter-element effects in which high energy fluorescence from heavier elements is absorbed by lighter elements, with a resultant enhancement of their fluorescence. Theoretical treatments of this problem have shown that X-ray fluorescence data can be corrected for these matrix effects by calculations based on fundamental constants. The measured fluorescence

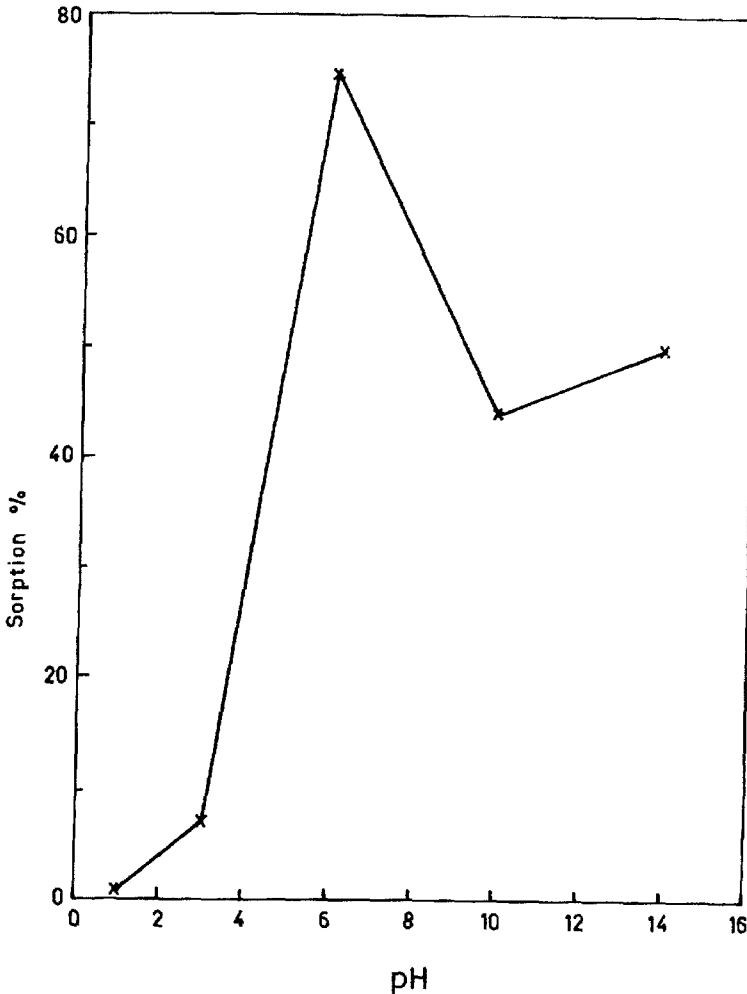


Fig. 3. Sorption of Th (at 0.97 mg/L concentration) onto pumice stone.

intensity, I_i , from an element i is related to the elemental concentration $\rho_i d$ in g cm^{-2} by the well known equation;

$$I_i = G_0 K_i (\rho_i d) [(1 - e^{-a\rho d}) / a\rho d]$$

where $G_0 = I_0 A_0 \Omega_1 \Omega_2 \text{cosec } \Phi$; I_0 and I_i are the intensity of primary and fluorescent radiation, respectively; A_0 is the area of primary radiation on the sample surface; Ω_1, Ω_2 are the solid angles for the excitation source and fluorescent intensity, respectively; K_i is the factor which depends on the excitation and detection efficiencies of element i (K_i contains all the fundamental parameters); Φ is the angle between the sample surface and primary radiation.

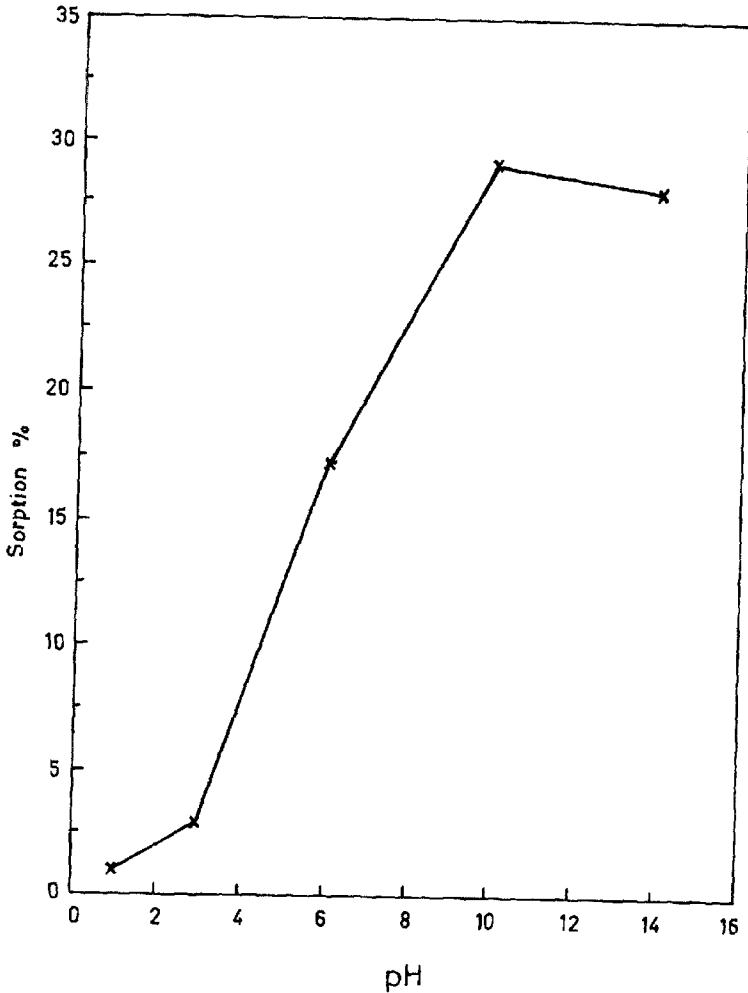


Fig. 4. Sorption of Sr (at 1 mg/L concentration) onto pumice stone.

The samples were thin and the specific X-ray intensities from the sample were measured with and without the pure element target positioned adjacent to the back of the sample.

$$apd = -\ln[(I_s - I_{s+t})/I_t]$$

where I_s , I_{s+t} and I_t are the fluorescent intensities from the sample, from the sample plus target and from the target alone, respectively.

3. Results and Discussion

The sorption capacity of pumice stone for Th ions is found to be higher than that for Sr and Cs ions as shown in Figure 1. The percentage sorption was calculated

by the following equation: percentage sorption of ion = $A/A_0 \times 100$, where; A is the concentration of ion in the sorbing material and A_0 is the concentration of the solution.

The percentage sorption of Th ion appears to increase on increasing the Th concentration of the stock solution in the range of 25–230 ppm, but begins to decrease with higher concentrations. A similar tendency has been observed for Cs ions. However, the percentage sorption for Sr ion is found to decrease gradually with increasing strontium concentration of the solution.

The results of Cs^+ sorption onto pumice powder are shown in Figure 2 and the maximum sorption was detected at pH 6. Cs sorption rapidly decreases at high pH values.

It is also found that the amount of Th absorbed by pumice stone increases at pH 6 and decreases at pH 10. The sorption of Th ions dependent on pH values is given in Figure 3.

Figure 4 shows that Sr concentrations increase by increasing the pH value of the stock solutions.

In all cases, the sorption capacity of pumice stone for uranium ions were found to be practically zero. This could originate from the pore size as well as the average cationic radius of the large complex cation of uranium.

4. Conclusion

The ion exchange and sorption properties of particular ions are very specific for an exchanger/sorbing material. Pumice stone could be a sorbing material for removal of Th^{4+} , Cs^+ and Sr^{2+} ions, but not for UO_2^{2+} from aqueous solutions. On the other hand the results indicate that natural pumice stone of Turkish origin shows a slight selectivity for Th^{4+} ions.

References

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