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MOBILITY OF Co^{2+} AND Sr^{2+} IONS IN THE CONTAMINATED SOIL: COLUMN STUDY

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ABSTRACT

The mobility of pollutants in the soil is closely related to their toxicity, and thus very important information for the selection of remediation strategies. In this study, leaching of Sr^{2+} and Co^{2+} ions from contaminated soil was investigated and compared under dynamic conditions. As a model soil, a sample from the "Vinča" Institute was tested. The soil artificially contaminated with inactive Sr^{2+} and Co^{2+} ions was packed in the columns, while acidic rain water was used as a leaching solution. Desorption of both cations was the most pronounced at the beginning, reaching the peak after the second day for Co^{2+} and after the seventh day for Sr^{2+} . During the course of experiment (37 days), cumulative percentages of desorbed Co^{2+} and Sr^{2+} were 0.7% and 19.8 %, respectively. The results indicated significantly higher soil affinity towards Co^{2+} ions. In spite of its higher total concentration in the soil, Co^{2+} mobility was much lower compared to Sr^{2+} .

INTRODUCTION

Radioactive isotopes of ^{90}Sr and ^{60}Co are important environmental pollutants which arise during regular operation of nuclear power plants and research reactors. They can end up in soil as a result of accidental spills of liquid radioactive waste. ^{90}Sr is also widespread due to above-ground nuclear testing. The remediation of contaminated soil includes various *in-situ* and *ex-situ* methods [1]. Mobility of the particular pollutant in the soil is the major factor influencing the selection of appropriate clean-up technology.

In this study, the mobility of ^{90}Sr and ^{60}Co was studied and compared using the soil sample from the "Vinča" Institute. This location serves as a nuclear waste repository, therefore, soil contamination with various radionuclides is possible.

EXPERIMENTAL

Surface sample of soil was taken to a depth of approximately 20 cm. The soil was dried in air atmosphere, crushed and sifted in order to separate a fraction of particle size < 2 mm for further experiments. Two portions of sifted soil were placed into plastic containers and mixed with the $5 \cdot 10^{-2}$ mol/dm³ of cobalt or strontium containing solution, at 1:2 solid/solution ratio. Inactive Co²⁺ and Sr²⁺ ions in the form of nitrate salts were used. The suspensions were allowed to equilibrate for one month. The soil was separated from the residual metal solution by filtering, and finally dried in air at room temperature. The total concentrations of Sr²⁺ and Co²⁺ ions in the contaminated samples were determined by ICP-OES method, using iCAP-6500 Duo (Thermo scientific, United Kingdom). Prior to measurements, each contaminated sample (0.5 g) was mixed with 7 cm³ of concentrated HNO₃ and 2 cm³ of 30% H₂O₂ and subjected to acid digestion in a microwave oven (CEM MDS 2100).

Two polypropylene bottles (0.5 dm³) were used to make appropriate columns. They were attached to the laboratory stands upside down, and the soil samples were placed between two PVC dredgers. The lower ends were covered with filter paper and layer of plastic pellets to retain the soil. At column top, Raschig rings were added to allow uniform elution and to minimize loss of evaporation. Contaminated soils (200 g) were packed in the columns. Rain water collected at the same site, was used as a leaching solution. Its initial pH was adjusted to 5 by a few drops of 0.1 mol/dm³ HNO₃, to mimic more aggressive - acid rain scenario. 100 cm³ of such solution were added daily to the top of each column, for a total time period of 37 days. The concentrations of metal cations in the leached fractions were determined.

RESULTS AND DISCUSSION

Chemical analysis showed that, under the same experimental conditions, total concentration of Co²⁺ in the contaminated soil was 8260 mg/kg, whereas 4450 mg/kg of Sr²⁺ was detected. The results indicated significantly higher capacity of soil towards Co²⁺ ions.

Desorption of studied cations from the contaminated soil varied as a function of time (Fig.1). Rapid grow of desorbed amounts was detected at the beginning of the process. The maximum was reached after 2 days for Co²⁺, whereas after 7 days for Sr²⁺. The longer time required to reach the maximum desorption, as well as the higher concentrations of leached Sr²⁺ ions confirm that a large quantity of Sr²⁺ was weakly associated with the soil. From the day 5, only small oscillations in Co²⁺ desorption were noted until the end of experiment. On the other hand, Sr²⁺ leached amounts

fluctuated, and reached another peak between 24. and 26. day. This illustrates the process complexity. Namely, various phenomena such as diffusion, convection, ion-exchange, specific cation sorption as well as formation and dissolutions of secondary phases, may occur simultaneously with different rates [2].

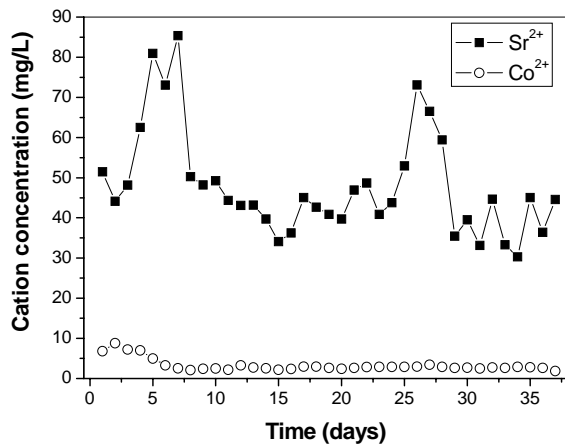


Figure 1. Time dependant concentrations of cations leached from contaminated soil.

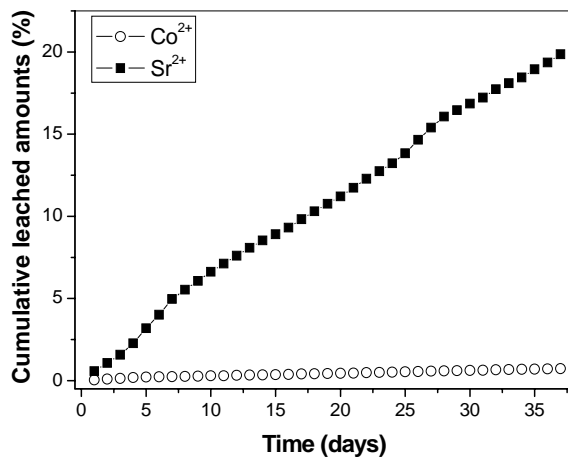


Figure 2. Cumulative percentages of leached metal cations

At the end of the experiment, cumulative percentages of desorbed Co^{2+} and Sr^{2+} (Fig. 2) were 0.7% and 19.8 %, respectively.

The inorganic contaminants can be bound to components of soil by several mechanisms [3]. Preferred sorption and considerably lower desorption of Co^{2+} in respect to Sr^{2+} , indicate different binding mechanisms of these ions to soil components. Due to high electronegativity, Co^{2+} ions are significantly subjected to ion-change reactions, and formation of complex compounds with organic phase of soil [4]. The weak alkaline reaction of the studied soil with water [5] enhances the sorption on oxides and aluminosilicates, and favors the hydrolysis and precipitation of Co^{2+} ions.

CONCLUSION

Although total concentration of Co^{2+} in the contaminated soil was initially higher in respect to Sr^{2+} , leached amounts were less significant. Higher electronegativity of Co^{2+} , together with weak alkaline soil/water reaction, influenced its significantly lower mobility. Due to the different mobility of Co^{2+} and Sr^{2+} cations in the contaminated soil, different remediation strategies should be considered.

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