• Analogs for Transuranic Elements

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A combined theoretical and experimental approach is being used to estimate the long-term environmental and biogeochemical behaviors of selected transuranic elements. Naturally-occuring elements that have chemical properties similar to those of the selected transuranic elements are being used. Examining the environmental biogeochemistry of these natural elements enables us to estimate the ultimate geochemistry and biological availabilities of the chosen transuranics. Investigations have included elemental sorption experiments on soil-and-solution mixtures; uptake studies on plants grown in a growth chamber and under field conditions; determinations of analog element availabilities as the analogs are moved from soils by chemical extractant solutions; and examination of samples collected from natural ecosystems.

The objective of this research is to estimate the effect that long-term (hundreds of years) environmental weathering has on the behavior of the transuranic elements americium and curium. This is achieved by investigating the actual behavior of naturally occurring rare earth elements, especially neodymium, that serve as transuranic analogs. Determination of the analog element behavior provides data that can be used to estimate the ultimate availability to man of transuranic materials released into the environment.

Chemical, biological, and physical forces that bring about environmental weathering reactions act nearly equivalently on the elements with similar chemical properties. The most significant chemical properties that are used to define elemental analogs include the predicted stable environmental oxidation states and the charge-to-ionic-radius ratio. On these bases, the naturally occurring lanthanide element, neodymium, is a chemical analog for the transuranics americium and curium. The behavior of the analog neodymium has been investigated in field experiments and in a laboratory growth chamber.

The interactions of the Nd^{+3}, Am^{+3}, and Cm^{+3} with soils and solutions have been investigated in short-term (24-hr or less) experiments. The results of these studies demonstrate that the sorption characteristics of these three elements on a Ritzville silty loam soil are similar. The variations in the distribution coefficients of these elements between the soil particles and the simulated soil solutions as a function of pH show excellent correlation between the elements. These data suggest that similar or identical mechanisms may function under a variety of conditions to control the total concentration of each of these elements held in solution. The soil chemistry of each element may be controlled by the same dominant factor(s).

Controlled plant-uptake investigations were performed under both field and growth-chamber conditions. Two types of plants used in this experiment were cheatgrass and snap beans. In these studies, the same chemical forms of Nd^{+3}, Am^{+3}, Cm^{+3} were added to the soils in which the plants were grown. The uptake of these elements can be expressed as a concentration ratio (elemental concentration in plant to elemental concentration in soil). The concentration ratios for these three nonessential trace elements were indistinguishable from one another. The stems and leaves of snap beans that were grown in a growth chamber had concentration ratios of 1.1×10^{-3} (americium), 1.3×10^{-3} (curium), and 1.2×10^{-3} (neodymium). The concentration ratios for the stem and leaves of the field-grown cheatgrass were 4.8×10^{-4} (americium), 2.5×10^{-4} (curium), and 6.5×10^{-4} (neodymium). These concentration-ratio data, together with the physical and chemical data for the determination of elemental distribution coefficients in soil-and-solution studies, have confirmed that, in these short-term investigations, the rare earth element neodymium is an adequate substitute for the transuranics americium and curium.

The principal goal of this research is to use knowledge of the biogeochemical behavior of naturally occurring (nonamended) neodymium to estimate the behavior of transuranics in the environment. These studies, which involve using added levels of the three elements, verify the similarities in the chemical and biological behaviors of americium, curium and neodymium.

Concentration ratios for the plant uptake of natural neodymium have been determined for several plant-and-soil systems. These natural soil systems contain transuranic elements from atmospheric fallout and thus afford an opportunity for comparing the concentration ratios of the naturally occurring analog with the fallout transuranics.

When comparing the concentration ratios of neodymium and americium (from natural soils) for seven different plant species, americium is from 25 to 120 times more biologically available than the neodymium, if the concentration ratios for neodymium are calculated by using the total soil-neodymium concentrations. This is due to the large fraction of soil neodymium that is geochemically bound within mineral matter and which is not available to biological systems for possible incorporation. However, when the concentrations of the chemically exchangeable neodymium in these soils are used for determining the plant concentration ratios, the concentration ratios for this "available" neodymium and for the fallout americium generally agree within a factor of two, which is an insignificant difference. These data are shown in Table 5.2. Thus, we have been able to define, through chemical means, the apparently biologically available analog element concentration in soils and to determine representative concentration ratios from these data.

Table 5.2. Plant Uptake of Analog and Transuranic Elements

Plant	Analog Element Conc. Ratio[a]	^{241}Am Conc. Ratio
Peas	9.6×10^{-3}	6.0×10^{-3}
Potatoes	4.6×10^{-3}	6.0×10^{-3}
Corn	7.0×10^{-3}	6.1×10^{-3}
Squash	3.9×10^{-2}	9.9×10^{-3}
Rye	2.9×10^{-3}	$<3.0 \times 10^{-3}$
Rice	4.3×10^{-5}	$<7.0 \times 10^{-3}$
Wheat	1.1×10^{-3}	2.5×10^{-3}

(a)Calculated from the concentrations of isotopically-exchangeable analog element in the soils

This investigation of the transfer of analog elements from soil to plants is now being extended to include transfer to additional food products and to transfer to man. The purpose of broadening this study is to estimate the analog element "dose-to-man" that the general population receives. The data for the transfer of the analogs from soil to plant and from plant to man can be used to estimate the transfer of transuranic elements from soil to plant to man after they have achieved a state of natural environmental equilibrium.