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Plutonium Mobility in Soil and Uptake in Plants: A Review¹

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ABSTRACT

A survey of the published literature pertaining to the movement of plutonium in soil and uptake in plants reveals that a major portion of the investigations pertain to soils developed under arid or semiarid climates. In some instances subsoil samples were used to describe plutonium adsorption characteristics and often short-term greenhouse experiments were used to predict plant uptake. Some recent long-term greenhouse studies indicate a substantially greater plant uptake of plutonium from a highly contaminated soil after 5 years of cropping as compared to the first year. It appears the most likely mode of plutonium entry into food chains leading to man would be that chelated with naturally occurring organic soil components. Chelation mechanisms have not been established.

Additional Index Words: chelation, plant uptake, adsorption, discrimination factor.

The projected accumulation of plutonium isotopes from the USA nuclear power industry is over 1000 megacuries by the year 2020 (5). Due to the vast increase in production and use of plutonium (e.g. implementation of fast-breeder reactors) the probability of plutonium contamination incidents will increase, and plutonium will remain the most important internal hazard in the nuclear industry (11). This potential source of radiation exposure is of concern not only to working members of the nuclear industry but also to members of the general public who fear accidental releases.

The food chain pathway to man by plant uptake of plutonium from soils appears to be a lower order risk when compared with direct inhalation or ingestion in short-term exposure situations. Research indicates that the discrimination factor of plutonium transfer from soils to plants (concentration in plants to concentration in soils) is the order of 10^{-4} to 10^{-6} and that plutonium is very immobile within the soil profile. However, recent radiological soil surveys near AEC's Rocky Flats, Colora-

dependent. In the pH range 2 to 8 approximately 98 to 100% of the plutonium was adsorbed from aqueous solution; at pH 8 to 12 the adsorption was lowered to 80%. Ultrafiltration data on trace quantities of plutonium (4×10^{-1} ppm) indicated formation of plutonium polymers at pH's above 2, and Rhodes concluded that plutonium was adsorbed to soil as positively charged polymers [Pu(OH)⁺ⁿ]. In the pH range 8 to 12 the adsorption was less due to change in the characteristics of the polymer. High concentrations of inorganic salts (4M NaNO₃ and 2M NH₄H₂PO₄) had no effect on the adsorption of plutonium on soil (96.5% plutonium adsorbed), but equal concentrations of organic salts (4M NH₄C₂H₃O₂) drastically reduced soil adsorption (58.9% plutonium adsorbed). Other acetate salts (calcium and barium) inhibited plutonium adsorption in a similar manner, and the magnitude of the inhibiting effect varied directly with the concentration of the acetate ion. Apparently a plutonium acetate complex anion was formed since 98.2% of the adsorbed plutonium on soil samples from equilibrated solutions of plutonium could be removed with five successive extractions of 8M NH₄C₂H₃O₂. Successive extractions with aqueous solutions of inorganic salts removed little soil adsorbed plutonium. The characteristics of plutonium in 0.25M oxalic acid solutions (pH 1) were highly indicative of anion complex formation, i.e., plutonium passed readily through a Visking dialyzing membrane and absorbed quickly on an anion-exchange resin but not on a cation exchange resin.

Hajek (4), working at Richland some 10 years later, evaluated possible plutonium mobility in the soil beneath one of the subsurface storage cribs. He concluded that movement by contact diffusion would be less than 10 cm after 2.4×10^5 years, and that a maximum of 0.1% of the plutonium could be leached by infiltrating ground water.

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