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Author
Price, Keith R.

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A Review of Transuranic Elements in Soils, Plants, and Animals[1]

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Keith R. Price[2]

ABSTRACT

Published information concerning the distribution and fate of neptunium, plutonium, americium, and curium in terrestrial ecosystems is reviewed, and areas needing further study are identified. In the final analysis of environmental quality, radionuclides with very long half lives will become increasingly important to man as they continually constitute a greater proportion of environmental radioactivity. The transuranic elements have been identified as the most hazardous radionuclide by-products of nuclear reactor operations. The relatively few studies conducted indicate that transuranic elements do not remain in solution in soils, plants, or animals, but organic complexes and chelation greatly enhance mobility. The elucidation of natural organic complexes and chelating agents has not been attempted. Oxidation state also influences mobility, but possible biological mechanisms permitting oxidation or reduction remain uninvestigated. Ingestion is the most important transfer mechanism in ecosystems, but assimilation of transuranics from natural food sources is mostly unknown. Evidence in the literature suggests three possible mechanisms leading to the observed increase in plant uptake with time: the formation of organic complexes or chelates, a buildup of radionuclide concentration at root surface, or the slow but continual uptake by perennial plants. Each of these mechanisms deserves further study.

Additional Index Words: radionuclides, neptunium, plutonium, americium, curium, radioactive waste, fallout, terrestrial ecosystems, nuclear reactors.

There have been many reasons to release anthropogenic materials into the environment in recent years, and it has been assumed that dilution and degradation of potentially harmful materials render them innocuous. Studies into the behavior of ecosystems, however, have shown that such materials may accumulate somewhere within the system even though the tendency is toward continual recirculation. Typical examples of accumulation with recirculation are radionuclides in aquatic environments. Radionuclides have been purposely released to the environment in two major instances, i.e., as by-products of the nuclear processing industry and the testing of nuclear weapons. The storage of significant amounts of processing wastes are restricted to localized and remote areas, and the amount of radioactive fallout has decreased steadily with the cessation of large atmospheric testing programs. Under current and proposed management practices there is no immediate hazard to man or biota where radioactivity is stored or exposed to the environment at nuclear processing plants or test sites. In the final analysis of environmental quality, however, radionuclides with very long half lives will increase in relative importance with time particularly where they are uncontained within the biosphere. A thorough knowledge of their behavior and distribution in natural systems seems prudent.

The most biologically harmful and longest lived radionuclides are those belonging to the actinide series. McKay (22) has pointed out that the transuranic elements neptunium, plutonium, americium, and curium are the most significant and hazardous radioelements produced from reactor operations. The frequency and importance of these radioelements in waste streams will increase in the future when breeder reactor fuels are reprocessed. Breeder reactor fuels undergo higher burnup rates and consequently contain higher proportions of transuranic elements. Health physics considerations have been reviewed by Denham (9) who noted that all transuranics except neptunium have higher specific activities than plutonium.

The transuranics generally have received only scattered attention regarding their behavior in the environment, and most biological studies have concerned plutonium (42). A symposium recently was held on various aspects of plutonium in the environment and is most valuable for the discussions on contemporary methodology (12). A comprehensive appraisal of available data on plutonium and other transuranics in aquatic environments has been prepared by Noshkin (28). Studies on ecological aspects concerning the dissemination of fallout plutonium in marine systems have been emphasized in past research. The few survey-type data available for freshwater systems indicate similarities to marine systems where sediments are the principle repository and sediment feeding organisms usually have high body burdens. There is evidence that plutonium is concentrated in aquatic food webs as are other radioelements. The purpose of this review is to assemble the published information relevant to the distribution and fate of transuranic elements in soils, plants, and animals of terrestrial ecosystems and to identify areas in need of further study.

SOILS

Problems associated with fallout plutonium in terrestrial environments have been reviewed by Krey, Bogen, and French (18) and Olafson and Larson (29), but the environmental fate of other alpha emitting radionuclides is not well known. Langham, Harris, and Shipman (21) and Langham (20) assessed the problem of plutonium contamination at the Nevada Test Site (NTS) and elsewhere and suggested that the hazard to man was minimal as long as particles deposited on vegetation and soil remained deposited. Romney, Mork, and Larson (37) observed a slight downward movement into undisturbed soil profiles at NTS during the 10 years following deposition. While the solubility of plutonium fallout particles in the presence of soil is poorly understood, plutonium infiltration to a depth of 12 cm was attributed to the downward movement of the high density particles and not solubilization. Mork (23) noted very similar downward movement in the same sampling areas 2 years post detonation where plutonium was found to be predominantly associated with $> 44\mu$ particles. Krey and Hardy (17) present results from a soil survey in the vicinity of Rocky Flats, Colora-

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[2] Senior Research Scientist, Battelle Northwest Lab., Richland, Wash. 99352.

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