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Uptake of Plutonium-238 by Plants Grown Under Field Condition as Affected by One Year of Weathering and Aging

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UPTAKE OF PLUTONIUM-238 BY PLANTS GROWN UNDER FIELD CONDITION AS AFFECTED BY ONE YEAR OF WEATHERING AND AGING[1]

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Uptake of ^{238}Pu by plants has been determined mainly in laboratory studies using limited quantities of soil and controlled environmental conditions of growth chambers (Wilson and Cline, 1966). These laboratory studies were short-term studies, presenting no data on the effect of residence time of plutonium in soil. However, a limited number of field studies have shown that aging of plutonium in the soil may effect its availability to plant. Romney (1970) found that concentration ratios of plutonium in field studies did increase with time. He suggested the possibility of soil microbes changing the chemical form of plutonium, making it more available for plant uptake.

Most field studies originated from an accidental release of transuranium elements to the soil; therefore, the time of release, amounts released, and chemical form of plutonium released are mostly unknown. At this laboratory, an experimental design was presented for field studies using lysimeters (Hinds and Cline, 1975). Known amounts of plutonium were

[1]This work was performed at the Hanford Reservation for the U.S. Energy Research and Development Administration by Battelle Pacific Northwest Laboratories, Richland, Washington under contract E(45-1)1830.

placed in retrievable containers and were exposed to environmental variables of the field.

The main objective is to study the long-term effects of weathering and aging on the availability of plutonium for plant uptake in an arid climate. This paper is an interim report of the results on the uptake of ^{238}Pu by four species of plants during the first two years of the long-term experiment.

METHODS

The safety and environmental requirements for placing transuranium elements in the field are stringent and exact. Transuranium elements must be contained in a retrievable condition at all times. Also, the containment zone must be isolated from animal populations so populations will not be contaminated and spread these elements to the surrounding environs. Water-tight lysimeters were constructed from P.V.C. plastic pipe, 13.2 cm in diameter and 1 m long. Then these containers were placed inside a slightly larger plastic sleeve buried endwise into the ground with the upper end exposed at the soil surface. The study zone was then enclosed in special wire mesh enclosure to exclude mammals and birds from the lysimeters (Hinds and Cline (1975).

After the enclosure was constructed and liners installed, the lysimeters were filled with a sandy loam soil. The soil was added to the lysimeters in three steps: (1) 17.5 kg (oven dry) of uncontaminated soil was added to the lysimeter.

This amount of soil filled the lysimeters within 15 cm of the top. The soil was settled into the lysimeters to a bulk density of about 1.27; (2) Then 105 g of soil (5% soil moisture) that had been thoroughly mixed in a V-blender with 1 mCi ^{238}Pu was poured in a uniform layer over the soil surface prepared above; (3) Then, 1400 grams (oven dry) of uncontaminated soil was placed over the thin layer of plutonium containing soil. The reason for the 10 cm cover with clean soil was a safety precaution to prevent direct exposure of ^{238}Pu soil at the surface. It also simulated the condition of burying a thin layer of contaminated soil that may have been formed by the percolation of water containing quantities of ^{238}Pu as in a waste pond. When the lysimeter was completely filled, a 5 cm edge of the lysimeter extended above the soil surface. After the lysimeters were filled, they were transported to the enclosure and placed into the holes dug into the ground.

By knowing amounts of soil added, tare weights of the containers, and the water-holding capacity of the soil (field capacity 25%), it is possible to calculate the water content of the soil by weighing the filled lysimeters. The proper amount of irrigation water that is needed to maintain the proper soil moisture for plant growth can be calculated using the gross lysimeter weight at field capacity or at any desired amount of soil water. The annual soil moisture rarely penetrates beyond eight decimeters depth in the profile in the arid climate in south-central Washington, so excessive amounts of soil water in 1 m long lysimeters is not likely.

Cheatgrass, Bromus tectorum, was seeded in October 1973 and reseeded itself thereafter. The only water that cheatgrass received was from natural rainfall. Before barley, Hordeum vulgare, and garden peas, Pisum nativum, were seeded in March of 1974 and 1975, the soil moisture was increased to 20% by adding irrigation water. Soil moisture was then maintained at nearly the 20% level throughout the growing season by frequent irrigations.

When seeds of the various species were developed to the late dough stage, the plants were harvested by clipping the stems just above the soil surface. The plant material was placed in paper bags and taken to the laboratory for processing. Tansy mustard, Descurainia pinnata, that seeded itself naturally was separated from the cheatgrass. The cheatgrass was separated into seeds and stem-leaves; peas into seeds, stems, leaves, and pods; and barley into seeds and stems-leaves. The plant material was oven dried at 60°C for 48 hours and weighed.

Plant material was ashed in a muffle furnace at 450°C, taken up in 2 N HNO_3 and analyzed for ^{238}Pu content by placing a certain amount of digest into vial and adding TTWC liquid scintillation gel and counting with an ambient temperature liquid scintillation counter (Price, 1972).

RESULTS AND DISCUSSION

The concentration of ^{238}Pu in tansy mustard was ∿30% higher than cheatgrass (entire plant) in 1974, but only 13%

higher in 1975. The amount of ^{238}Pu accumulated in both species of plants in 1975 was 3 to 5 times higher than in 1974 (Figure 1). The annual differences are difficult to explain this time of the experiment.

The concentrations of ^{238}Pu were lower in the seeds than in the vegetative parts in all the plant species measured (Figure 1 and 2). Figure 2 shows that pea leaves contained the highest concentration followed by stems, then pods and the lowest in the seed. The barley leaves and stems contained more ^{238}Pu than the seed, but the differences among the parts were less than in the peas.

An interesting difference between the irrigated plants, peas and barley, and the non-irrigated plants, cheatgrass and tansy mustard, was that the concentrations of ^{238}Pu in the irrigated plants were 2 to 3 times lower in the second year plants while the non-irrigated crops were 3 to 4 times higher in the plants grown the second year. A possible reason may be that the increased water added to the soil by irrigation changed the configuration of the plutonium in the soil profile. Also, rainfall in 1974 was nearly two times the average, and the increased water in the soil profile may have extended the roots of the non-irrigated plants through a larger portion of the soil profile than in 1975, so a larger percent of the roots may have been in contact with the thin layer of contaminated soil during 1975. However, the water was maintained in the irrigated soils at nearly the same content both years, possibly causing some movement of ^{238}Pu from the thin layer of contaminated soil to soil below. This possible dilution of soil concentration may have reduced uptake. Sometime in the near future, soil from several lysimeters will be sampled to determine if the ^{238}Pu has moved within the profile. Wildung and Garland (1974) showed that plutonium moved downward in the root system and the root is a better vehicle for the movement for plutonium throughout the soil profile than the downward movement with soil water. Routson showed plutonium moved very slowly by passing water through a soil column.

CONCLUSIONS

Less ^{238}Pu was concentrated in the seeds than in the vegetative parts in all plant species. Leaves contained more ^{238}Pu than the stem or pods., and the monocots had lower concentrations of ^{238}Pu in their tissues than the dicots. Irrigation of plants affected the uptake of ^{238}Pu, especially on the year-to-year changes in the amount of the element accumulated in the plant parts. Several more years of data must be analyzed to determine if this phenomenon is real. Soil profiles must be studied to determine what configuration changes may occur in the ^{238}Pu in the soil. Wildung and Garland (1974) show that soil microbes change the chemical form of plutonium in the soil and the organic complexes that are formed are more available for plant uptake.

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FIGURE 1. Concentrations of ^{238}Pu in leaves and seeds of cheatgrass and in whole plant of tansy mustard grown in 1974 and 1975 - Sub-surface thin layer configuration.

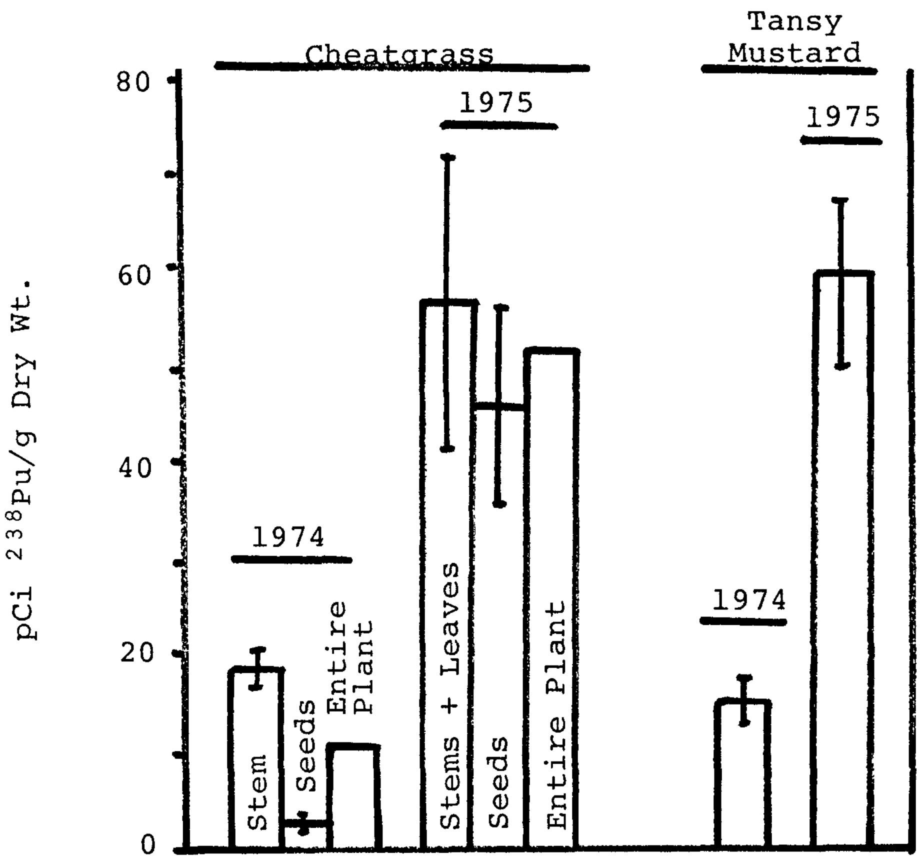

FIGURE 2. Concentrations of ^{238}Pu in the various plant tissues of barley and peas grown in 1974 and 1975 - Sub-surface thin layer configuration.