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BIOLOGICAL TRANSPORT OF RADIONUCLIDES AT LOW LEVEL WASTE STORAGE SITES

Annual Report
October 1, 1977 - September 30, 1978

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Prepared for
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Office of Nuclear Regulatory Research
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Abstract

The major objective of this years' work under NRC Contract Fin. No. B3027-6 has been to provide or prepare to provide backup information that can help monitor low-level waste storage facilities.

To accomplish this major objective several small objectives were formulated and accomplished.

(1) Capability for assay of several transuranic elements in sequence was developed at both UCLA and UCB labs.

(2) Capacity to sample vegetation under statistically meaningful circumstances was further developed by a frequency distribution study of radionuclides and stable elements in plants under reasonably uniform conditions.

(3) Reasons for a several fold-range in the concentration ratios used to predict plant uptake of transuranium elements were demonstrated and hence it will be necessary to recognize this reality in model building and in any kind of nuclear siting.

(4) The objective of developing a more accurate multiple regression model of soil parameters on the concentration ratio of five different transuranium elements in plants involved in the food chain of man was vigorously pursued and a preliminary version will soon be available.

(5) The objective of determining how much radionuclides can be mobilized by deep rooting of plants from depths in soil was put into an experimental test which is not yet completed.

(6) The relative importance of stable strontium vs calcium on radiostrontium transport and of stable Cs vs potassium on radiocesium transport under waste management conditions received preliminary study.

(7) Several waste management soils were characterized (Fayette, Fuquay, Carjo, and Puye) as preliminary steps to growing plants on those soils with spiked levels of radionuclides and with actual waste chemicals otherwise added (cooperative with LASL).

(8) Plans were developed for FY 1979 studies and activities and include field plant work at Maxey Flats, Kentucky; review and synthesis of the vast store of published information relating to models and ideas used in the decision making processes with the view to identify gaps, errors, false assumptions in that data base; and to verify and confirm old models but with parameters carefully identified and quantified.

LOW-LEVEL WASTE MANAGEMENT STUDIES - 1978 and 1979

FY 1978

We have responded to the request that this contract be made relevant to low-level waste management problems. In fiscal year 1979 the project will be completely waste-management oriented. The following studies and activities were made or started in fiscal year 1978. Research is largely confirmatory.

1. Chemical and mineralogical characterizations were made of nine soil samples collected by the LASL group from four different low-level waste-management sites. The results are included elsewhere in this report.

2. Samples of soil from sites mentioned above were spiked with several different appropriate radionuclides and also received actual liquid waste material which also contain the same radionuclides as the spikes but at lower levels. These soil samples are to be received from LASL for plant growth experiments at UCLA.

3. A comprehensive review of the subject of radionuclide uptake by plants was made and published as NUREG CR-0336. This 87-page document contains 322 references and discusses uptake characteristics for 13 radionuclides. This review forms a working basis for our continued studies with low-level waste management and will be a companion to our annotated bibliography of transuranium element uptake by plants (NUREG/CF-0158).

4. Confirmatory experiments were made to verify the hypothesis that stable strontium is more important than calcium in determining uptake of radiostrontium from soil and that stable cesium is more important than potassium in determining uptake of radiocesium from soil. Although these experiments are not fully complete the hypothesis seems to be verified.

It is noted that considerable stable strontium and stable cesium are found in some low-level waste sites. It was also determined that large quantities of stable strontium cycle in nature and that smaller but significant quantities of stable cesium cycle in nature. These very much can determine transport characteristics of the respective radionuclides.

5. A low-level waste storage site operated by the Department of Energy in Frenchman Flat at the Nevada Test Site was visited and management procedures ascertained.

6. An experiment is being conducted in which alfalfa is being grown in plastic tubes 10 feet deep and in which radionuclides are placed at the lower depth. This is part of a study designed to determine the practical significance that deep rooting can have on radionuclide uptake from such places as low level waste-burial sites.

7. It is believed that the other studies that we have been engaged in during the past 2½ years have much relevance to low-level waste management. These studies are mentioned in other places throughout this report. Of particular value will be the completed 7-soil transuranium element study of plant uptake which will result in development of new simple regression models of soil characteristics on plant uptake. The seven soils represent a wide cross section of agricultural soils throughout the United States of America and allow a wide range of parameters and within parameters for the models. They will provide a standard baseline for our waste-management uptake studies.

FY 1979

Our FY 1979 NRC activities will be divided into three different but related categories.

1. Field work at the Maxey Flats, Kentucky low-level waste burial site and at other similar sites as necessary.

2. Documentation from the literature data base of the state of knowledge of the parameters and associated data going into models currently being used in decision making in nuclear waste management and related technology and sufficient synthesis of that knowledge to identify areas where change, proof, or confirmation are needed.

3. Actual model verification under simulated field and waste management conditions of soil to plant transfer of radionuclides.

Under item 1, field plots are to be established in the fescue planted on top of the trenches, and adjacent to the trenches, in the vegetation just off the site, and in areas where radionuclides can be expected to be moving from the site. The plots are to be sampled on a regular basis as to be determined later and will serve as a radioecology evaluation of the plant portion of the ecosystem. In addition to these plots, a deep rooted plant, possibly alfalfa, will be grown in a network of plots on certain of the trench sites to ascertain the potential for movement to biota of radionuclides from the burial trenches. The capillary water will also be collected in porous cups for radioactive assay for correlation with plant uptake. Spectrographic analyses will also be made to determine any trace metal movement from wastes to food chains.

Under item 2, a comprehensive document and its synthesis will be prepared to pull together that information which we need to know to understand and solve waste management problems.

Under item 3, the work in which we have been engaged will be completed in an orderly manner and the data will be used as a test of models currently being used to describe food-chain dynamics. In addition, experiments are being established and others will be planned to simulate waste management conditions through which transfer coefficients can be determined or verified for the specific parameters.

Site Visit to Maxey Flats, Kentucky

On December 7, 1978 A. Wallace and E. M. Romney with NRC representatives and persons from other laboratories visited the Maxey Flats low-level waste shallow burial site. This brief report will serve to give our tentative appraisal of the site.

The site does offer some important research possibilities if new somewhat similar sites are developed in the humid areas of the USA. If there are to be no such new sites in the USA, then research possibilities still exist to a certain extent because of problems related to decommissioning.

As stated in our discussions associated with the site visit meeting, shallow burial sites could probably be satisfactorily managed if water were kept from entering them, if plant roots were kept out of them, and if small animals were prevented from entering them. It was stated that at least the first two would be easier to achieve at sites in arid Nevada than at those in high rainfall humid areas.

We remained at Morehead overnight of December 7 and were therefore in the area when thunderstorms and flash floods put about 3-4 inches of rain onto the site. Runoff streams about 5 to 10 feet apart cascaded down the rock faces in torrents. Initially clear water was involved but as the rain intensity increased it was obvious that even the hill tops under natural vegetation were experiencing erosion. If significant amounts of water penetrates the rock formations at Maxey Flats it would be only because the trenches allow water penetration which then has no way to escape except through the rocks and the fissures. This further emphasizes the need to keep water out of the trenches if the radionuclides are to stay put.

The newspaper clippings of December 9, 10, and 11, 1978 are relevant. Maxey Flats need see such intense storms only once every few years to explain all the radionuclide movement that has occurred. A search of past rainfall records is indicated not only for this site but also for all past and proposed shallow burial sites. Areas of intense storms should be avoided where possible.

After inspection of the site at Maxey Flats, we concluded, tentatively, that it would not be overly difficult to achieve a close to an ideal shallow burial area at Maxey Flats. Since the site is upon top of a hill some 300 or more feet high the only source of water to it is from rainfall. It also appeared that the overwhelming majority of water was surface runoff over the edges. It was also ascertained that most of the rainfall does come in a few large storms that have leaching-erosion characteristics (flash floods).

Covering of the site with an impervious material to achieve 100% runoff with no erosion would solve radionuclide transport problems for as long as the covering material were intact. Heavy plastic covered with packed clay was suggested as a cover. A foot deep of concrete would cost around $4 million for the entire site and may last for a few hundred years. It would have the advantage of allowing some alternate uses of the area. The 50 inches of rainfall (28 million gallons for year) could be collected from the concrete surface and used for industrial purposes on the site.

We heard that it was necessary to keep the lower rock formations saturated with water. Since their water holding capacity is very low a few pipes down to them could easily add enough water to keep them saturated.

It would appear that, if water, plants and animals could be kept out of the trenches, the site could continue to be used even for new disposal in additional trenches. As a trench is filled and still open it may be wise to use pumps to keep water from accumulating in the bottom. One of the most important research needs would be on procedures to keep water out of them. In the meantime some of the trenches could be used for valuable research purposes. One of these research purposes is that of growing a deep-rooted plant species to determine if and how much radionuclides can be mobilized under such conditions. We will propose that this be done and it is one way in which our group could participate in studies there.

Los Angeles Times 3
Sat., Dec. 9, 1978—Part I

Rescuers evacuated elderly and young persons from several blocks in Portland, Tenn., as rain-swollen creeks left their banks. Several eastern Kentucky families were evacuated from their homes after 3 to 4 inches of rain fell in some sections in 24 hours.

The forecast for today called for rain along the Atlantic coast from southern Maine to South Carolina.

Five West Virginia counties were placed under a small-stream flood warning Friday, and the National Weather Service said additional heavy rain expected through the night could cause widespread river flooding.

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6 Part II—Sun., Dec. 10, 1978 Los Angeles Times 2★

Cracks Found in Rain-Swollen Dam in Kentucky; 10,000 Flee

From Times Wire Services

More than 10,000 persons were evacuated Saturday after Corps of Engineers inspectors discovered cracks in an earthen dam two miles upstream from Paintsville in eastern Kentucky.

Rain-swollen Paint Creek had raised the level behind the dam to within 5 feet of its 95-foot-high top by noon Saturday; but an afternoon cold front changed the rain to snow, and that appeared to have stabilized what officials had called a dangerous situation.

By late Saturday afternoon, the water level behind the dam had dropped about 7 inches. Officials said they expected the rate of decline to increase. They said that, if the water continued to recede, residents probably would be allowed to move back into their homes late today.

Civil Defense officials said that if the dam had burst, a 12-foot wall of water could have been unleashed.

The evacuation was only part of Kentucky's weather problems. Statewide flooding, brought on by three days of steady downpours, led Gov. Julian Carroll to declare an emergency. Two persons drowned.

Thousands of persons fled their homes in Kentucky and West Virginia, and frigid temperatures accompanying the flooding turned roads to ice.

Floodwaters swept through at least 150 homes in West Virginia, forcing scores of families to flee. Other evacuations were reported in Virginia.

Russellville, Ky., was under water, and 25 homes and 30 bridges were damaged by flooding in Kentucky's Magoffin County.

Authorities reported that 60 to 70 Kentucky roads were impassable. Freezing rain spread along the Ohio River from Louisville to Cincinnati and south to Bowling Green, Ky. The bodies of a woman and a child were found in a submerged car at Bowling Green. Their identities were withheld.

About two-thirds of Hamlin, W.Va., was covered by water.

★ Los Angeles Times Mon., Dec. 11, 1978—Part I 5

Capitol Cut Off by Flood in Kentucky

From Times Wire Services

Floodwaters filled the streets of more than half of downtown Frankfort, Ky., Sunday, forcing 1,000 persons from their homes, interrupting water, gas and phone service and cutting off the state capitol.

Three days of rain had sent the Kentucky River over its banks in the worst flood on record in the city of 22,000.

Schools were ordered closed until after the holidays.

Swollen by 3 inches of rain, the river inundated nearly all of south Frankfort and low-lying areas in north Frankfort.

Water extended from the river banks a half-mile to the capitol, almost the only dry structure in south Frankfort.

Water was so deep on some streets that boats had to be used to evacuate residents. Workers were hindered also by icy streets when temperatures plunged into the teens early Sunday.

"It'll probably be late Tuesday or sometime Wednesday before we'll be letting any of them go back to their houses," Joe Jennings, the city's fire chief and civil defense director, said.

Gov. Julian Carroll declared a state of emergency for flood stricken parts of the state.

At least two deaths were attributed to the rising waters. The bodies of Tiny Wright, 22, and her son, Terry Lee, 5, of Bowling Green, were found in their car, which apparently had been driven into 5 feet of water.

More than 500 national guardsmen were stationed around Kentucky, to help evacuate residents and to prevent looting.

At Paintsville, Ky., about 10,000 residents moved back to town Sunday evening as the water level dropped behind a cracked and leaking dam. The streets had been deserted for 32 hours.

In Ohio and West Virginia, hundreds of families have been evacuated along the Ohio River, which flooded at some spots over the weekend and is expected to crest above flood stage at several points—including Cincinnati—later this week.

Preparation and Characterization of Soils Used in NRC Experiments

Large-Tank Experiments

Seven soils, representing major soil types which are typical of major food crop producing areas of the United States, were collected and prepared for use in large tank experiments designed to simulate agricultural conditions. These experiments of necessity must be conducted under special materials handling conditions because of their transuranic element contents. A glasshouse at UCLA was modified and equipped for that purpose. The methods of preparing the transuranic spikes and the materials involved have been reported earlier. Plow-depth top soil was used in these experiments.

The large batch mixing operations were done in radiological safety facilities at the Nevada Test Site provided tnrough arrangements with the Nevada Operations Office. Dry blending of the soil, radionuclide spikes and fertilizers amendment was done with a 5 ft^3 Patterson-Kelly V-type mixer. The potting tanks are stainless steel lined, fiberglass-coated wooden tanks constructed to meet long-term storage and retrievability specifications and standards. Blending time for each mix was one hour. The amounts of each soil placed in the tanks and the final radionuclide activity levels are listed in the following table. Five replicates containing the same weight were prepared for each soil type; however, our desire to maintain common soil volume in each tank resulted in variation of weight between soil types due to differences in soil density. The total amounts of transuranic elements mixed in each tank of soil were 0.05 mCi ^{237}Np, 5.00 mCi$^{239\text{-}240}$Pu, 0.5 mCi ^{241}Am, and 0.5 mCi ^{244}Cm.

Soil	Weight kg	^{237}Np	$^{239\text{-}240}$Pu	^{241}Am	^{244}Cm
			nCi/gram air dry soil		
Yolo	177.1	0.28	28.23	2.82	2.82
Egbert	93.3	0.54	53.59	5.36	5.36
Aiken	141.9	0.35	35.24	3.52	3.52
Holtville	200.3	0.25	24.96	2.50	2.50
Lyman	156.4	0.32	31.97	3.20	3.20
Mablis	179.4	0.28	28.87	2.79	2.79
Sharpsburg	164.1	0.30	30.47	3.05	3.05

The tanks of soil prepared at NTS were transported to UCLA for continuing plant uptake experiments. They were initially cropped with wheat followed by soybeans. It became necessary to add additional lime to the Lyman and Mablis soils, and this was done before planting all soils to garden peas as the third crop. Radiochemical analysis of plant materials is in progress and some findings are presented elsewhere in this report.

Soil Classification and Profile Description

The classification and profile descriptions of soils used for the NRC project follow the 7th Approximation Series (Soil Survey Staff, 1975, Soil Taxonomy, SCS/USDA Agriculture Handbook No. 436).

YOLO SOIL

The typifying soil is a member of the fine-silty, mixed, thermic, Typic Xerorthents.

The Yolo series consists of well-drained silt loams and silty clay loams on alluvial fans. Slopes are 0 to 2 percent. The soils formed in alluvium from sedimentary rocks. Elevation ranges from 25 to 400 feet. The average annual temperature is 60°F., the annual rainfall is 16 to 22 inches, and the frost-free season is about 270 days. In uncultivated areas the vegetation is annual grasses and forbs. Yolo soils are associated principally with Brentwood and Reiff soils.

In a typical profile, the soil is grayish-brown to pale-brown silt loam and silty clay loam that extends to a depth of more than 60 inches. In some areas the soil is silty clay loam throughout the profile.

Yolo soils are used for orchard, row crops, forage crops, truck crops, irrigated pasture, dryfarmed grain, wildlife habitat, and recreation.

Horizon	Depth Inches	Profile Description
Ap1	0 to 2	Grayish-brown (2.5Y 5/2) silt loam, very dark grayish brown (10YR 3/2) when moist; moderate, thick, platy structure: hard, friable, slightly sticky and plastic; many micro and very fine random roots; many micro and very fine interstitial and tubular pores; neutral (pH 6.7); abrupt, slightly wavy boundary. (2 to 10 inches thick)
Ap2	2 to 8	Grayish-brown (2.5Y 5/2) silt loam, dark brown (10YR 3/3) when moist; massive; probable tillage pan; hard, friable, sticky and plastic; many micro and very fine random roots; common micro tubular pores; neutral (pH 7.1); clear, wavy boundary. (3 to 10 inches thick)
A11	8 to 19	Grayish-brown (2.5Y 5/2) silt loam, dark brown (10YR 3/3) rubbed, and very dark grayish-brown (10YR 3/2) coatings when moist; weak, coarse, subangular blocky structure; hard, friable, slightly sticky and plastic; common micro and very fine random roots; many micro and very fine tubular pores and clusters of interstitial pores that have wormcasts; few thin clay films on ped faces and continuous thin clay films in pores; neutral (pH 7.2); clear, wavy boundary. (6 to 12 inches thick)
A12	19 to 26	Grayish-brown (2.5Y 5/2) silt loam, very dark grayish brown (10YR 3/2) when moist; massive; slightly hard, friable, slightly sticky and plastic; many micro and very fine and few fine random roots; many micro and very fine tubular pores; neutral (pH 7.3); clear irregular boundary. (6 to 13 inches thick)

AIKEN SOIL

The typifying soil is a member of the kaolinitic, mesic, Xeric Haplohumults

The Aiken series consist of well-drained soils that are underlain by deeply weathered andesitic conglomerate at a depth of 4 feet or more. These soils are gently sloping to moderately steep on wide, smooth ridges and the sides of ridges Slopes are 3 to 30 percent. Elevations range from 2,500 feet to 5,000 feet. The average annual precipitation, including snow, is 40 to 60 inches, average annual temperature is 55°F., and the frost-free season is 140 to 240 days. Vegetation is mainly coniferous forest and associated hardwoods. Aiken soils are associated principally with Cohasset, Josephine, McCarthy, Musick, and Sites soils.

In a representative profile, the surface layer is brown and reddish-brown, medium acid loam and clay loam about 24 inches thick. The subsoil is red and yellowish-red, medium acid and strongly acid heavy clay loam and clay that extend to a depth of more than 72 inches.

Aiken soils are used for woodland and for deciduous fruit orchards.

Horizon	Depth Inches	Profile Description
O1&O2	3 - 0	Litter and duff
A11	0 - 3	Brown (7.5YR 4/3) loam, dark brown (7.5YR 3/3) when moist; weak, medium, subangular blocky structure parting to strong, very fine, granular; slightly hard, friable, nonsticky and nonplastic; many very fine roots and common fine and coarse roots; many very fine and fine interstitial and tubular pores; medium acid, abrupt, smooth boundary.
A12	3 - 9	Brown (7.5YR 4/3) loam, dark brown (7.5YR 3/3) when moist; massive parting to strong, very fine, granular structure; slightly hard, friable, nonsticky and slightly plastic; many very fine roots and common fine to coarse roots; many very fine and fine interstitial and tubular pores; medium acid; clear, smooth boundary.
A31	9 - 15	Brown (7.5YR 4/4) loam, dark reddish brown (5YR 3/3) when moist; strong, very fine, granular structure; slightly hard, very friable, slightly sticky and slightly plastic; many very fine roots and common fine, medium and coarse roots; many very fine and fine interstitial and tubular pores; medium acid; clear, wavy boundary.
A32	15 - 24	Reddish-brown (5YR 4/4) clay loam, dark reddish brown (5YR 3/4) when moist; strong, very fine, granular structure; hard, friable, slightly sticky and slightly plastic; medium acid; clear, smooth boundary.

EGBERT SOIL

Egbert muck, a member of the Histosol soil order (sample not classified further), exhibits an alternation of organic material with a higher admixture of alluvial mineral. It is commonly acid and contains soluble salts, and it is somewhat dense in the upper part of the subsoil. The Egbert soils occur in comparatively flat areas where, under natural conditions, they are saturated with water and support a dense growth of tules, reeds, and similar hydrophytes. Broadly speaking, but with several exceptions, Egbert muck tends to occupy somewhat higher upstream situations than do less altered soils.

Only a general profile description is available for this soil. Egbert muck has a moderately altered to well-decomposed 14-inch surface soil that grades almost imperceptibly into an upper subsoil layer of slightly more dense but otherwise similar material, which, in turn, grades into a lower subsoil layer of loose permeable material. The surface soil consists of dark-gray soft granular to fluffy muck containing few or no fragmental remains of plants. The reaction is moderately acid, as the pH value ranges from 5.5 to 6.0, and the content of organic matter is about 40 percent or less. No distinct demarcation exists between the surface soil and the subsoil, which consists of dark-gray moderately soft fine-grained peaty muck. Horizontal-lying fragments of reeds and tules are numerous in the subsoil. The upper subsoil layer has a slightly more acid reaction, with a pH value of 5.5 or less, and a slightly higher organic-matter content than the surface soil. The material is rather firm moderately dense consistence and more or less platy structure. Such features are barely discernible in the normally wet soil but are more distinct in dry exposures. The lower subsoil layer has a much less acid reaction, with a pH value of about 6.0, and a higher content of organic matter. Small lenses and strata of less altered brown fibrous peaty material occur in the lower part of the subsoil in some places, as do similarly thin and erratic strata of light grayish-brown soft silty clay. In some of the latter places, charred and carbonized plant fragments are present immediately beneath the mineral stratum, suggestive of an earlier inundation of sediment-laden water preceded by a period of fires. The subsoil rests abruptly on the light-gray mineral substratum at a depth ranging from 4 to 20 feet or more.

HOLTVILLE SOIL

CLASSIFICATION:	Typic Torrifluvent, clayey over loamy, montmorillonitic (calcareous), hyperthermic family.
VEGETATION:	Cultivated, fallow after barley.
CLIMATE:	Average annual precipitation 2.72 inches; average annual temperature, 72°F. Average frost-free growing season 314 days, January 29 to December 9.
PARENT MATERIAL:	Recent lacustrine sediments.
TOPOGRAPHY:	Lacustrine basin, nearly level, less than 1-percent slope to north.
ELEVATION:	90 feet below sea level.
DRAINAGE:	Runoff slow, permeability slow, well drained, water table not observed.
SOIL MOISTURE:	Dry in Ap, slightly moist below.

Horizon	Depth Inches	Profile Description
Ap	0 - 10	Pinkish gray (7.5YR 6/2) silty clay, brown (7.5YR 4/2) moist; weak coarse subangular blocky and weak very coarse platy; very hard, very firm, sticky, and plastic; few fine and very fine random roots; mildly alkaline (pH 7.8); strongly effervescent; clear smooth boundary.
C1	10 - 22	Light-brown (7.5YR 6/4) silty clay, brown (7.5YR 4/2) moist; weak medium subangular blocky and weak very coarse platy; very hard, firm random roots; few discontinuous very fine pores; mildly alkaline (pH 7.8); strongly effervescent; vertical lenses of silt, few fine white gypsum efflorescences; abrupt smooth boundary.
C2	22 - 33	Light-brown (7.5YR 6/4) silty clay, brown (7.5YR 4/4) moist; moderate coarse platy; very hard, friable, slightly sticky and plastic; very fine and very fine roots; mildly alkaline; strongly effervescent; horizontal silty partings; few fine and medium gypsum efflorescences in cracks; clear smooth boundary.
C3	33 - 50	Pink (7.5YR 7/4) loam matrix, yellowish brown moist, with light-brown (7.5YR 6/4) silty clay microstrata, brown (7.5YR 5/4) moist; massive; hard, friable, nonsticky and slightly plastic; very few very fine roots in vertical cracks; clear smooth boundary.

LYMAN SOIL

CLASSIFICATION:	Coarse loamy, mixed, frigid Typic Haplorthods.
VEGETATION:	Spruce and fir.
PARENT MATERIAL:	Glacial till.
PHYSIOGRAPHY:	Glaciated upland.
SLOPE:	6 percent.
DRAINAGE:	Well drained.

Horizon	Depth Inches	Profile Description
O2	0 - 3	Black (5YR 2.5/1) organic mat; very friable; many roots; extremely acid; abrupt wavy boundary.
A2	0 - 2	Pinkish gray (7.5YR 6/2) very fine sandy loam; weak fine and medium granular structure; very friable; many roots; less than 5 percent coarse fragments; very strongly acid; abrupt wavy and broken boundary.
B21h	2 - 4	Very dusky red (2.5YR 2.5/2) very fine sandy loam; weak medium subangular blocky structure; very friable; many roots; less than 5 percent coarse fragments; extremely acid; clear wavy and broken boundary.
B22ir	4 - 7	Mixed red (2.5YR 4/8) and dark brown (10YR 3/3) silt loam; weak fine subangular blocky structure; very friable; many roots; less than 5 percent coarse fragments; extremely acid; gradual wavy boundary.
B23ir	7 - 15	Dark brown (10YR 3/3) very fine sandy loam; very friable; common roots; less than 5 percent coarse fragments; very strongly acid; clear wavy boundary.
B24ir	15 - 24	Yellowish brown (10YR 5/6) silt loam; weak fine subangular blocky structure; very friable; many roots; 10 percent coarse fragments; very strongly acid; clear wavy boundary.
B3	24 - 28	Grayish brown (2.5Y 5/2) fine sandy loam; weak medium platy structure; friable; many very fine roots; 10 percent coarse fragments; very strongly acid; clear wavy boundary.
C1	28 - 42	Dark grayish brown (2.5Y 4/2) gravelly fine sandy loam, gravelly sand and loamy sand strata; massive; loose to friable; few roots; 20 percent coarse fragments; strongly acid; gradual wavy boundary.

MABLIS SOIL

The typifying soil for this mapping unit is a member of the fine-loamy, siliceous, thermic family of Plinthic Paleudults. This mapping unit is typified by soils with dark grayish brown fine sandy loam Ap horizons, yellowish brown loam B21t horizons, and mottled sandy clay loam B23t horizons containing 10 per cent plinthite nodules. These soils occur on broad level uplands with slopes of less than 2 per cent.

Horizon	Depth Inches	Profile Description
Ap	0 - 7	Dark grayish brown (10YR 4/2) fine sandy loam; weak medium granular structure; friable; medium acid; abrupt smooth boundary.
B21t	7 - 26	Yellowish brown (10YR 5/6) loam; weak medium subangular blocky structure; friable; few plinthite nodules in lower part; common very thin patchy clay films on faces of peds; strongly acid; gradual wavy boundary.
B22t	26 - 54	Yellowish brown (10YR 5/6) sandy clay loam; common medium distinct strong brown (7.5YR 5/6) and few medium faint light yellowish brown (10YR 6/4) mottles; moderate medium subangular blocky structure; friable firm around plinthite nodules, 5 percent plinthite nodules; common very thin patchy clay films on faces of most peds; strongly acid; gradual wavy boundary.
B23t	54 - 71	Yellowish brown (10YR 5/8) sandy clay loam; few medium prominent light gray (2.5YR 7/2), common medium distinct red (2.5YR 4/8) and strong brown (7.5YR 5/8) mottles; weak medium subangular blocky structure; friable, firm around plinthite nodules; common medium pores, 12 per cent plinthite nodules; many patchy clay films on faces of peds and in some pores; very strongly acid.

SHARPSBURG SOIL

The Sharpsburg series are fine, montmorillonitic, mesic Typic Argiudolls. They typically have very dark brown friable silty clay loam A horizons, brown and dark yellowish brown firm heavy silty clay loam B2 horizons that are mottled in the lower part, and mottled yellowish brown and grayish brown friable light silty clay loam B3 and C horizons.

Horizon	Depth Inches	Profile Description
Ap	0 - 8	Very dark brown (10YR 2/2) silty clay loam, dark gray (10YR 4/1) dry; weak fine granular structure; friable; slightly acid; abrupt smooth boundary.
A12	8 - 11	Very dark brown (10YR 2/2) silty clay loam; weak very fine subangular blocky structure parting to moderate fine granular; friable; medium acid; gradual smooth boundary.
A3	11 - 17	Very dark grayish brown (10YR 3/2) silty clay loam; some brown (10YR 4/3) peds; moderate very fine subangular blocky structure; friable; medium acid; gradual smooth boundary.
B21t	17 - 24	Brown (10YR 4/3) silty clay loam; weak medium prismatic structure parting to moderate fine subangular blocky; firm; common very dark gray (10YR 3/1) coats; thin discontinuous clay films; strongly acid; gradual smooth boundary.
B22t	24 - 32	Brown (10YR 4/3) and dark yellowish brown (10YR 4/4) silty clay loam, few fine faint distinct strong brown (7.5YR 5/6) and fine faint grayish brown (2.5Y 5/2) mottles; moderate medium prismatic structure parting to moderate fine subangular blocky; firm; thick discontinuous clay films; few fine dark bodies; strongly acid; gradual smooth boundary.
B23t	32 - 44	Dark yellowish brown (10YR 4/4) silty clay loam, many fine and medium faint grayish brown (2.5Y 5/2) mottles, few fine distinct yellowish brown (10YR 5/6) mottles; weak medium prismatic structure parting to weak medium subangular blocky; friable; few thin discontinuous clay films; many very fine dark bodies; medium acid; gradual smooth boundary.

Chemical and Physical Properties of Soils

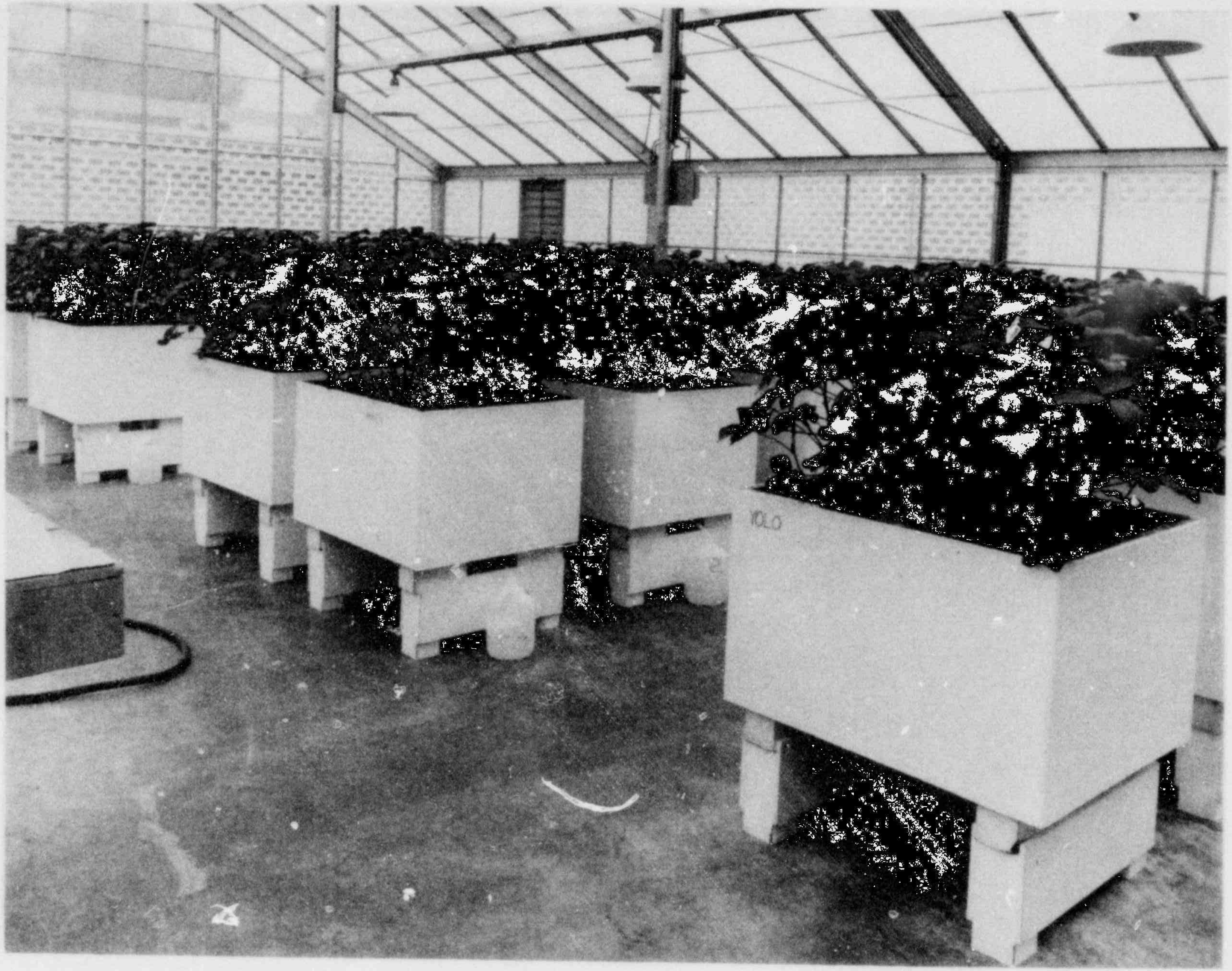
Samples of less than 2 mm size fraction of each soil were prepared for chemical and physical analysis. The samples were analyzed by Edward S. Babcock and Sons, Riverside, CA, and certificates of analysis are on file at UCLA. Results are summarized in the following table for procedures as described: pH was determined by the saturated paste method. The saturation extract was used for determining electrical conductance and extractable calcium, magnesium and sodium. The exchangeable cations--calcium, magnesium, potassium and sodium, were determined in the 1-10N NH_4OAc extract and expressed as ppm of the sieved, air dry soil. Cation exchange capacity in milliequivalents per 100 gm dry soil was determined by the sodium acetate method, by the Ba-TEA method, and by summation of ammonium acetate extract. Only the sodium acetate results are given in the tabulated values. Iron, zinc, copper and manganese were determined in the 1-2 DTPA extract (1 part soil to 2 parts DTPA solution) and expressed as ppm of the sieved air dry soil. Extractable chloride, nitrate nitrogen and sulfate sulfur were determined in the 1-5 water extract and expressed as ppm of the sieved air dry soil; phosphate phosphorus was determined in the 1-20 0.5M $NaHCO_3$ extract and expressed as ppm of the sieved air dry soil. Organic material content was estimated by the loss on ignition method, and particle size analysis was done by the sieving and hydrometer method.

Chemical and Physical Properties of Soils

SOIL PROPERTIES	YOLO	EGBERT	AIKEN	HOLTVILLE	LYMAN	MABLIS	SHARPSBURG
pH, paste	6.7	7.2	6.0	7.8	5.0	5.3	5.9
EC x 10^3 (mmho/cm^3)	1.1	1.4	0.2	2.9	0.2	1.0	0.4
Extractable Cations:							
Calcium, ppm	80	120	12	230	8	75	50
Magnesium, ppm	60	36	3	62	4	27	11
Sodium, ppm	15	44	8	125	3	13	7
Exchangeable Cations:							
Calcium, ppm	3000	9000	1500	4800	32	1000	2500
Magnesium, ppm	1200	1200	120	120	14	360	300
Potassium, ppm	680	1240	580	850	30	100	300
Sodium, ppm	50	520	30	360	1	1	1
Cation Exchange Capacity	25	60	15	30	15	15	20
DTPA Extractable TE:							
Iron, ppm	16	190	38	8	50	28	26
Zinc, ppm	2	4	1	1	1	2	1
Copper, ppm	3	1	1	2	1	1	2
Manganese, ppm	68	37	34	7	22	56	64

Chemical and Physical Properties of Soils (cont.)

SOIL PROPERTIES	YOLO	EGBERT	AIKEN	HOLTVILLE	LYMAN	MABLIS	SHARPSBURG
Extractable Anions:							
Chloride, ppm	80	230	10	130	90	35	20
NO_3-N, ppm	10	29	10	22	10	26	15
SO_4-N, ppm	190	220	20	350	40	10	10
PO_4-P, ppm	11	15	8	13	8	20	13
Loss on ignition, %	5	45.2	16.4	4	8.3	4.8	5.5
Sand, %	27	70	70	29	65	55	19
Silt, %	58	30	28	39	33	33	56
Clay, %	15	0	2	32	2	12	25



View of soybean crop growing in radionuclide contaminated soil at UCLA in large containers of soil representing a cross section of soil types throughout the USA.

MINERALOGICAL EXAMINATION OF SOILS USED IN THE NRC STUDY

A number of different soils are being used in this project, by both the LASL and the UCLA - Berkeley groups. It is felt that it is necessary to have these soils well characterized chemically, physically, and mineralogically. This will enable development of a predictive capability with regards to radionuclide movement into plants and through soils, when used in conjunction with the information being acquired in the on-going studies of radionuclide movement in soils and plant uptake of the radionuclides. This section reports the X-ray analysis of these soils.

Soils

Two sets of soil samples were studied by X-ray analyses*. The first set contained four California soils: Yolo, Egbert, Aiken, and Holtville. Three additional soils, one from each of these three states: Massachusetts (Lyman), Alabama (Mablis), and Nebraska (Sharpsburg) were also studied. The second set of samples was provided by Los Alamos Scientific Laboratory (LASL). The LASL samples were received with the following documentation:

Container #	Soil	Weight (gm)
12	Fayette Ap	1241
13	Fayette B	1219
14	Fayette C	1212
15	Fuquay Ap	1491
16	Fuquay A_2	1630
17	Fuquay B_{21}	1234
18	Fuquay C	1288
19	Carjo B	1209
20	Puye C	1119

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* The variations between procedures for set #1 and set #2 soil samples were attempts to reduce sample processing time. Soil samples of set #2 were analyzed 5 months after the set #1 samples.

Soil Pretreatment

Preliminary preparation of the soil samples was by air drying, 2mm sieving, mixing, and V-blending.

Separation of the < 2μ Fraction

The first part of the separation of the < 2μ fraction was dispersal of the soil sample. The first set of samples, Yolo, Egbert, Aiken, Holtville, Lyman, Mablis, and Sharpsburg,was dispersed in distilled water. The second set of samples, Fayette Ap, B, and C, Fuquay Ap, A_2, B_{21}, and C, Carjo B, and Puye C, was dispersed in a $Na_6(PO_3)_6 + Na_2CO_3$ solution. The following amounts of soil were dispersed to obtain clay for analysis:

Set #1	Soil, 2mm sieved	Weight (gm)	Set #2	Soil, 2mm sieved	Weight (gm)
	Yolo	5		Fayette Ap	10
	Egbert	10		Fayette B	10
	Aiken	10		Fayette C	10
	Holtville	3		Fuquay Ap	10
	Lyman	7		Fuquay A_2	10
	Mablis	7		Fuquay B_{21}	10
	Sharpsburg	3		Fuquay C	10
				Carjo B	10
				Puye C	10

The soil samples were placed in 250 ml wide-mouth polyethylene bottles. One hundred twenty-five ml of distilled water was added to the set #1 samples. The composition of the solution added to the set #2 samples was 35.70 gm $Na_6(PO_3)_6$ + 7.94 gm Na_2CO_3 made to 1 liter with distilled water and used at the rate of 2 ml/gm per 125 ml total volume. The set #1 samples were capped and shaken in a horizontal position at medium speed on a platform shaker for ∿ 18 hours. These bottles were set aside until collection of the < 2μ fraction. The set #2 samples were shaken by hand for ∿ 20 seconds and placed in an ultrasonic cleaner (Heat Systems Ultrasonics Inc. automatic cleaner model HS-10) for 5 minutes using only the cleaning function. The bottles were shaken to resuspend the samples and allowed to stand overnight. The next day the bottles were shaken again and centrifuged at 4° C and 9,000 rpm for 50 minutes (SerVall refrigerated automatic RC-3) using a Sorvall-type GSA head. The supernatant was decanted by vacuum pipette to prevent loss of suspended clay. Measurements of the supernatant pH were made to indicate the need for adjustments to solutions significantly below pH 9.0. Destabilization of the clay suspension occurs at lower pH values. Two distilled water washes were made by shaking, centrifuging, and decanting as before. The bottles were refilled to full volume with distilled water.

Supernatant pH

soil	dispersal supernatant	1st water wash	2nd water wash
Fayette Ap	9.8	9.7	9.7
B	9.3	9.4	9.5
C	9.7	9.3	9.8
Fuquay Ap	9.5	9.6	9.6
A_2	10.0	9.6	9.4
B_{21}	9.2	9.3	9.2
C	9.2	9.3	8.9
Carjo B	10.0	9.8	9.6
Puye C	10.0	9.9	9.7

The second part of the separation was collection of the < 2μ soil fraction. Each set of bottles was vigorously shaken to resuspend the soil sample. The < 2μ fraction was separated by pipetting off the upper 7 cm of each suspension after an established time period. A table based on Stokes' Law[1] fixed the collection time for set #1 at 5 hours 13 minutes for 23° C and for set #2 at 5 hours 28 minutes for 21° C. The bottles were refilled to volume and the collection procedure was repeated. Collections from set #1 were repeated until the suspension appeared only slightly turbid. Only three collections were made from set #2.

Enough 4N NaCl was added to each set #1 collection bottle to make the NaCl concentration at least 1N causing flocculation of suspended clay. Low yields of clay from the Lyman soil required a more effective dispersal method. Two 5 gram samples were each dispersed in 125 ml $Na_6(PO_3)_6$ +

Na_2CO_3 solutions (93.75 gm $Na_6(PO_3)_6$ + 6.25 gm Na_2CO_3 made to 1 liter and used at the rate of 50 ml/liter per 40 gm of soil) by shaking for 30 minutes. The collection procedure was as before. The following number of collections was made for each set #1 soil:

soil	collections	soil	collections
Yolo	4	Lyman (dispersed in $Na_6(PO_3)_6$ + Na_2CO_3)	3
Egbert	6	Mablis	4
Aiken	6	Sharpsburg	4
Holtville	3		
Lyman	3		

Pre-X-ray Preparation[2]

Supernatant was vacuum pipetted from the set #1 collection bottles. The flocculated material was transferred to two 50 ml polyethylene centrifuge tubes. One third of the material was placed in one of the tubes for immediate use and the remaining material was stored in the second tube for later use. Samples to be prepared for X-ray treatment were centrifuged for 10 minutes at 8,000 rpm and the supernatant was decanted. Each sample was washed twice with 25 ml of 1N NaCl by resuspending the clay pad and centrifuging for 10 minutes at 8,000 rpm. The supernatant was decanted and the clay was washed three times with 5 ml of 1:2 glycerol:ethanol solution. The first two centrifugations were for 10 minutes at 8,000 rpm and the last was for 20 minutes at 10,000 rpm. The supernatant was decanted and the tube was inverted to drain excess glycerol overnight. The remaining clay samples of Egbert, Lyman, Lyman (dispersed in $Na_6(PO_3)_6$ + Na_2CO_3 solution), and Nebraska were treated to destroy organic matter. Each sample was mixed with 25 ml of a pH 9.6 $NaHClO_3$ (bleach) solution and placed in a hot tap water bath to stand overnight. The samples were centrifuged for 10 minutes at 5,000 rpm and the supernatant was decanted. Two 15 ml 1N NaCl washes were made before proceeding to the glycerol:ethanol treatment.

The set #2 collected clay suspensions were concentrated by centrifuging for 15 minutes at 11,000 rpm and discarding the supernatant. The clay pads were resuspended in ∿ 5 ml of distilled water and quantitatively returned to the original collection bottles. Each suspension was concentrated until a 20 ml aliquot would contain at least 0.5 gm of clay. The following concentrated clay suspension volumes were obtained:

soil	horizon	volume (ml) approx.
Fayette	Ap	200
	B	400
	C	350
Fuquay	Ap	150
	A_2	150
	B_{21}	400
	C	300
Carjo	B	250
Puye	C	350

Each collection bottle was shaken to resuspend all clay material. A 20 ml aliquot was drawn from each bottle and transferred to a 50 ml polyethylene centrifuge tube. Five ml of 5N NaCl was added to each tube. The tubes were capped, shaken, and set aside for at least 10 minutes. All tubes were centrifuged for 10 minutes at 8,000 rpm. The supernatant was decanted. Twenty ml of distilled water and 5 ml of 5N NaCl were added to each tube except Fuquay A_2. Another 20 ml aliquot of clay suspension was added to this tube with the 5 ml of 5N NaCl. The clay pads were resuspended and the tubes were centrifuged for 10 minutes at 8,000 rpm. The supernatants were decanted and each sample was washed twice with 10 ml of 1:2.5 glycerol:ethanol solution. The first centrifugation was for 5 minutes at 8,000 rpm and the second was for 10 minutes. The supernatants were decanted and the tubes were inverted to drain any remaining supernatant.

The clay rods for X-ray analysis of both sets of samples were prepared by the following procedure:[3] the clay pad in a centrifuge tube was transferred by spatula to the side of the tube and thoroughly mixed. Glycerol was very sparingly mixed into the sample and the sample was carefully heated at 105° C to give a stiff consistency. Part of this prepared material was transferred to a specially modified No. 23 or 24 hypodermic needle and 0.5 cm rods were extruded using a special plunger. One rod was placed near and parallel to an edge of a 0.75 cm square 0.25 mil piece of Mylar. All rods were placed on a 1-inch square tile and stored in a glycerol-saturated atmosphere until use.

Dehydrated clay rods were prepared by heating to various temperatures in a muffle furnace.[4] A sufficient number of rods for each sample was placed on a separate tile and transferred to the muffle. The rods were gradually heated to 300° C and maintained at that temperature for several hours. The rods to be immediately X-rayed were transferred on a separate tile to a silica gel dessicator to cool to room temperature. The remaining rods were heated to 500° C and 650° C as needed.

X-raying of Clay Rods[5]

For glycerated samples, the piece of Mylar with a clay rod was mounted with some glycerol on a specially constructed specimen holder. For heat-treated samples, the specimen holder was carefully wiped free of all glycerol. A piece of 0.75 cm square 0.25 mil Mylar was folded in half and the heat-treated rod was placed in the fold. The Mylar and rod were mounted on the specimen holder with the dry-mount hardware.

A specimen holder was fitted to the end of a collimator tube on a G.E. XRD X-ray diffraction machine. A flat cassette-type camera was used and the focal length was set at 5.0 cm. The collimator had a pinhole of 0.02 inch. The X-ray tube emitted filtered Cu radiation ($\lambda = 1.5404$) and was operated at 40 kV and 20 mA. The X-ray film (Ilford industrial G) was exposed for 45 minutes. The film was developed in Kodak X-ray developer for 8-15 minutes depending on temperature and the working age of the solution. The first fixer-stop bath was for 15 seconds and the second was for 15 minutes.

Qualitative Interpretation of X-ray Diffraction Diagrams

Processed X-ray films were placed on a light table and measurements were made of the diameters of the diffraction circles using a vernier measuring device. Measurements were recorded to 0.005 mm. Relative intensities and general qualities of the circles were noted. A set of tables[5] was used to convert the diameter of each circle to Å units corresponding to each diffracted beam. The tables were generated from the equation:

$$d = \frac{\lambda}{2 \sin \left[\tfrac{1}{2} \arctan \left(L/2 \cdot 1/f \right) \right]}$$

where d is in Å, $\lambda = 1.5405$ Å for Cu radiation, L = diameter of the diffraction circle in cm., and f = 5.0 cm, the focal length of the camera. The calculated Å values were compared with known values[7] of soil colloids for preliminary interpretations. The absence or presence of certain diffraction circles upon heating was used to confirm the identity of particular soil colloids. The absence of 4.8 Å circles from the four Fuquay 300° C heat-treated samples confirmed the presence of Gibbsite instead of Chlorite. Dr. Isaac Barshad, Soil Mineralogist, Department of Soils and Plant Nutrition, U.C. Berkeley, confirmed the final interpretations for the set #1 samples and assisted with those for the set #2 samples.

Set #1

Soil	dÅ	Relative Intensity	Description	Identification
Yolo	18.66	S	broad diffuse	Montmorillonite
	14.49	S	broad	Vermiculite interlayered with Montmorillonite
	10.00	W	broad diffuse	Mica
	7.22	W	broad diffuse	Vermiculite
	4.56	W	inner border of a broad band	Montmorillonite
	4.18	VW	outer border of a broad diffuse band	Kaolinite
	3.58	W	broad diffuse	Kaolinite
	3.38	S	sharp	Quartz
	2.60	VVW	broad diffuse	amorphous Fe
Egbert	14.23	W	broad diffuse inner border of a broad diffuse band	Vermiculite
	7.04	W	outer border of a broad diffuse band	Kaolinite
	5.48	VW	broad diffuse	Ca oxalate?
	4.48	S	inner border of a broad diffuse band	Kaolinite
	4.02	W	outer border of a broad diffuse band	Feldspar
	3.55	W	diffuse	Montmorillonite
	3.35	S	sharp	Quartz
	3.21	W	diffuse	Feldspar
Egbert (minus organic matter)	20.38	W	broad diffuse	Montmorillonite
	14.42	S	sharp	Vermiculite
	7.27	W	broad diffuse	Kaolinite
Aiken	14.10	S	broad	Vermiculite
	7.22	S	broad	Kaolinite
	4.87	MW	broad diffuse	Gibbsite
	4.40	S	broad diffuse	Gibbsite
	4.03	W	outer border of a broad diffuse band	Feldspar
	3.57	W	broad diffuse	Kaolinite
	3.34	W	sharp	Quartz
	2.68	VW	diffuse	amorphous Fe
Holtville	18.44	S	broad	Montmorillonite
	9.72	S	broad diffuse	Vermiculite
	7.22	W	sharp	Kaolinite
	4.50	S	sharp	Mica (hk0)
	4.14	W	outer border of a broad diffuse band	---
	3.53	VW	diffuse	Kaolinite
	3.33	VS	sharp	Quartz
	2.57	W	broad	---

Soil	dÅ	Relative Intensity	Description	Identification
Lyman (dispersed in $Na_6(PO_3)_6$ + Na_2CO_3)				
	14.20	MS	diffuse	Vermiculite
	4.49	MS	sharp	Kaolinite
	4.25	W	diffuse	---
	3.36	S	sharp	Quartz
	2.57	VW	broad diffuse	---
Mablis				
	14.42	S	broad	Vermiculite
	7.17	MS	diffuse	Kaolinite
	4.81	S	sharp	Gibbsite
	4.35	S	broad	Gibbsite
	4.12	MS	broad	Kaolinite
	3.52	W	broad diffuse	Kaolinite
	3.32	S	sharp	Quartz
Sharpsburg				
	18.33	S	broad diffuse	Montmorillonite
	10.22	W	diffuse	Mica
	7.28	VW	diffuse	Kaolinite
	4.51	S	sharp	Mica (hk0)
	3.35	S	sharp	Quartz
	2.58	W	diffuse	---

Set #2

Fayette				
Ap	18.72	WM	broad diffuse	Montmorillonite
	14.59	WM	broad diffuse	Vermiculite
	10.16	WM	broad diffuse	Mica
	7.14	WM	sharp	Kaolinite
	4.46	M	sharp	Mica (hk0)
	4.24	M	broad	Quartz
	3.53	W	broad	Kaolinite
	3.35	S	sharp	Quartz
	3.21	VW	broad	Feldspar
	13.63	VW	broad diffuse	
	10.60	M	broad diffuse	
300° C	7.58	WM	diffuse	
	4.63	M	sharp	
	4.41	M	sharp	
	3.46	VS	sharp	

Soil	dÅ	Relative Intensity	Description	Identification
Fayette B	18.55	VS	broad diffuse	Montmorillonite
	14.10	M	broad diffuse	Vermiculite
	9.96	W	very broad diffuse	Mica
	7.07	M	sharp	Kaolinite
	4.47	M	broad	Mica (hk0)
	4.26	M	diffuse	Quartz
	3.58	W	broad diffuse	Kaolinite
	3.34	S	sharp	Quartz
300° C	10.09	S	broad diffuse	
	7.08	M	sharp	
	4.51	M	sharp	
	4.25	WM	diffuse	
	3.34	VS	sharp	
Fayette C	19.05	VS	very broad	Montmorillonite
	14.59	M	broad diffuse	Vermiculite
	10.32	VW	very broad diffuse	Mica
	7.30	WM	sharp	Kaolinite
	4.59	S	sharp	Mica (hk0)
	4.35	W	broad diffuse	Kaolinite
	3.75	W	broad diffuse	---
	3.42	S	sharp	$Fe_2O_3H_2O$?
300° C	10.53	S	broad	
	7.56	VW	broad diffuse	
	4.61	S	sharp	
	4.43	VW	diffuse	
	3.44	S	sharp	
Fuquay Ap	14.23	M	sharp	Vermiculite
	7.23	M	sharp	Kaolinite
	4.85	W	diffuse	Gibbsite
	4.46	W	diffuse	Kaolinite
	4.22	M	diffuse	---
	3.56	M	broad diffuse	Kaolinite
	3.35	VS	sharp	Quartz
300° C	13.64	M	broad diffuse	
	7.16	S	broad	
	4.44	M	diffuse	
	4.24	M	diffuse	
	3.55	WM	broad diffuse	
	3.34	VVS	sharp	
500° C	12.25	WM	very broad diffuse	
	4.63	M	sharp	
	4.42	M	sharp	
	3.60	VW	diffuse	
	3.45	VS	sharp	

Soil	dÅ	Relative Intensity	Description	Identification
Fuquay				
A_2	14.31	S	sharp	Vermiculite
	7.18	M	sharp	Kaolinite
	4.87	W	broad diffuse	Gibbsite
	4.44	WM	diffuse	Kaolinite
	4.26	WM	diffuse	---
	3.55	W	diffuse	Kaolinite
	3.34	VS	sharp	Quartz
	14.26	S	very broad diffuse	
	7.52	S	sharp	
300° C	4.63	WM	diffuse	
	4.41	M	sharp	
	3.68	WM	broad diffuse	
	3.45	VVS	sharp	
	12.70	S	very broad diffuse	
	5.11	WM	very diffuse	
500° C	4.50	S	sharp	
	4.24	S	sharp	
	3.49	W	broad diffuse	
	3.34	VVS	sharp	
Fuquay				
B_{21}	14.36	WM	broad diffuse	Vermiculite
	7.15	VS	broad	Kaolinite
	4.82	M	sharp	Gibbsite
	4.38	M	broad diffuse	Kaolinite
	4.14	M	broad diffuse	---
	3.56	S	sharp	Kaolinite
	3.36	VW	diffuse	Quartz
	7.16	VS	sharp	
	4.45	M	inner border of a broad diffuse band	
300° C	3.56	S	broad	
500° C	4.66	M	broad diffuse	
Fuquay				
C	14.42	WM	diffuse	Vermiculite
	7.18	VS	sharp	Kaolinite
	4.82	WM	diffuse	Gibbsite
	4.42	S	inner border of a broad diffuse band	Kaolinite
	4.14	WM	outer border of a broad diffuse band	---
	3.55	S	sharp	Kaolinite
	13.52	W	very broad diffuse	
	7.46	VS	sharp	
300° C	4.62	M	inner border of a broad diffuse band	
	3.68	S	broad	

Soil	dÅ	Relative Intensity	Description	Identification
Carjo				
B	19.92	M	broad diffuse	Montmorillonite
	10.71	[illegible]	broad diffuse	Mica
	7.49	[illegible]	broad diffuse	Kaolinite
	4.63	M	sharp	Mica (hk0)
	4.39	WM	broad diffuse	Kaolinite
	4.19	WM	broad diffuse	Kaolinite
	3.89	W	broad diffuse	---
	3.66	W	broad diffuse	---
	3.44	S	sharp	$Fe_2O_3 \cdot H_2O$?
	3.23	M	broad	Quartz
	3.06	VW	diffuse	Feldspar
	10.06	M	broad	
	7.16	W	broad diffuse	
300° C	4.47	WM	broad	
	4.26	W	broad diffuse	
	4.05	W	diffuse	
	3.74	W	broad diffuse	
	3.34	S	sharp	
	3.22	WM	diffuse	
Puye				
C	19.30	M	very broad diffuse	Montmorillonite
	10.22	WM	broad diffuse	Mica
	7.16	W	broad diffuse	Kaolinite
	6.46	W	broad diffuse	---
	4.50	M	sharp	Mica (hk0)
	4.26	WM	diffuse	Quartz
	4.05	WM	diffuse	Feldspar
	3.75	WM	broad diffuse	---
	3.29	S	sharp	Quartz
	3.21	S	sharp	Feldspar
	10.60	M	broad diffuse	
	7.40	W	diffuse	
300° C	4.65	M	broad	
	4.41	W	broad diffuse	
	4.19	WM	broad diffuse	
	3.90	M	sharp	
	3.67	VW	broad diffuse	
	3.45	S	narrow sharp	
	3.32	M	diffuse	

Semi-Quantitative Interpretation of X-ray Diffraction Diagrams

The basis for making semi-quantitative interpretations from soil clay X-ray diffraction diagrams is the comparison of an unknown diagram with a set of diagrams of known composition. The sets of standardized diagrams were provided by Dr. Isaac Barshad. Only diagrams having the same components may be compared. Initially, the first order lines of the two major components on a diagram are studied for relative intensity. Components are estimated from comparisons with standard diagrams having similar relative intensities of the two major components.

% Composition of the < 2µ Soil Fraction

Soil	Montmorillonite	Vermiculite	Kaolinite	Mica	Quartz	Gibbsite	Feldspar	Fe_xO_y	Amorphous Fe and Al, Organic matter
Yolo	54	5	26	4	4				7
Egbert (minus organic matter)	4	36	34		2		1		23
Aiken		17	67			4	3	9	
Holtville	57	3	29	2	4				5
Lyman		64	2		4				30
Mablis		57	28	1	4	5			5
Sharpsburg	40	10	20	15	5				10
Fayette Ap	20	14	36	18	7		1		4
B	35	27	18	8	5				7
C	40	22	30	7					1
Fuquay Ap		45	35		9	5			6
A_2		45	35		10	2			8
B_{21}		30	60		1	6			3
C		12	77			5			6
Carjo B	23		27	15	6		3		26
Puye C	21		22	22	4		5		26

1. Ref. Particle Fractionation and Particle-Size Analysis. p. 548, P. R. Day, Agronomy No. 9, Part I, American Society of Agronomy, Inc. 1965.

2. Ref. X-ray Analysis of Soil Colloids by Modified Salted Paste Method. p. 352, I. Barshad, Clays and Clay Minerals, Monograph No. 5, Pergamon Press. 1960

3. Ref. Ibid., p. 353.

4. Ref. Ibid., p. 359.

5. Ref. Ibid., p. 353.

6. Ref. These tables contained the Å equivalent values for the diffraction circle diameters in cm. obtained for a flat cassette-type camera with a 5 cm focal length. Dr. Isaac Barshad provided these tables.

7. Ref. Handout for Soil Science 213 taught by Dr. Isaac Barshad at U.C. Berkeley, p. 122-128.

SAMPLING PROBLEMS IN STUDIES OF PLANT UPTAKE AND PLANT CONCENTRATIONS OF ACTINIDE ELEMENTS WHEN DEALING WITH PLANT POPULATIONS

Plant sampling for studies to determine concentrations of actinide elements in populations of plants presents formidable problems if the activity is from plant uptake from the soil. If the activity is from aerial deposition either from resuspension or other sources, sampling procedures are much more simple because of a greater chance for more uniform distribution.

The problem of sampling for plant uptake in populations was the motivating factor for the study that follows. The frequency distribution obtained for ^{241}Am illustrates the real world to a degree even though the experiment was conducted under close to ideal conditions. The nature of the problems involved are discussed in that report and must be considered in all of the field work involving plants.

Simply, neither on a macro basis nor on a micro basis are the radionuclides uniformly distributed in soil. This cannot be achieved easily by blending under laboratory conditions. The only way to achieve such would be to add the soil to be contaminated in a completely dispersed condition all at once to an infinite volue of solution containing the radionuclide under observation. The problem is that there are far more clay particles than atoms of actinide unless very high levels of radionuclide are encountered.

In the field the problem is compounded because of types of unequal distribution in addition to that one just mentioned. It is very possible that a sampling of an area in which plants are taking up radionuclides from soil may result in an error of two or more orders of magnitude.

The $\log_e$ normal distribution found in the study in the next report illustrates a consistent but wide variation which will demand either large plant sample sizes or/and large numbers of samples. Duplicate or triplicate samples cannot be meaningful unless they themselves represent many plants from an area to be studied.

FREQUENCY DISTRIBUTION OF ^{241}Am IN A POPULATION OF BUSH BEAN PLANTS GROWN IN SOIL IN A GLASSHOUSE

Abstract: Thirty bush bean plants (Phaseolus vulgaris L. C.V. Improved Tendergreen) were grown in a glasshouse in soil contaminated with 14,000 dpm ^{241}/g soil. Another set of 30 were grown in similar soil but with 100 μg DTPA chelating agent/g soil. The coefficient of variation for ^{241}Am in the different kinds of leaves assayed varied from 54 to 124%. The variability was not related to the presence of the chelating agent. The frequency distribution appeared to be $\log_e$ normal.

Introduction

The problem of great variation in the concentration ratio (C.R.) of actinide elements in plants (ERDA, 1975; Schulz, 1977) may be in part related to its uneven distribution in soils. The particle size problem is well known (Fowler and Essington, 1977; Wallace and Romney, 1977). Ball milling of soils is necessary to get reasonably uniform samples for analysis. In addition to the particle size there is another problem which we will call the carrier-free problem. One gram of soil containing about 15% clay could have about 2 x 10^{16} individual clay colloids. If 14,000 dpm ^{241}Am per g soil, as in the present experiment, were blended uniformly with the soil, each individual clay colloid would have only 3 x 10^{-4} atoms of ^{241}Am or one clay colloid of each 2900 would on the average have one. It is, of course, totally impossible to even approach that degree of uniform distribution. Most likely the overwhelming majority of clay colloids would have none (even much more than the one in 2900) but that a few would have several

Table 1. Concentrations of ^{241}Am and C.R.'s for population of bush bean plants grown in soil with and without chelating agents.

	N	Mean	SD	CV	SEM	Range	C.R. of Mean	SD of C.R.	CV of C.R.	SEM of C.R.	C.R. Range
		dpm/g dry wt		%	dpm/g dry wt		ratio	ratio	%	ratio	
						Primary leaf					
No DTPA	30	73.0	51.2	70	9.3	18-220	0.0052	0.0037	70	0.0007	0.0013-0.0157
DTPA	30	22587	12224	54	2233	5498-62592	1.61	0.873	54	0.160	0.393 -4.47
						1st and 2nd trifoliate leaves					
No DTPA	30	48.2	39.7	82	7.2	5-135	0.0034	0.0028	82	0.0005	0.0004-0.0096
DTPA	30	809.0	619.7	77	113.0	251-3274	0.057	0.044	77	0.008	0.0179-0.234
						3rd and 4th trifoliate leaves					
No DTPA	30	78.5	48.0	61	8.8	9-229	0.0056	0.0034	61	0.0006	0.0006-0.0164
DTPA	30	744.0	919.6	124	167.9	184-2996	0.053	0.066	124	0.012	0.013 -0.214

or many. Even though the ^{241}Am then may be uniformly mixed insofar as samples of 1 g are concerned, it is far from uniformly mixed even under the best of conditions.

The purpose of this experiment was to reasonably uniformly mix ^{241}Am in soil, grow a population of plants and then determine the type of frequency distribution involved under these conditions. Such results would help to determine sampling procedures for field conditions and to set limits on the validity of results.

Materials and Methods

The ^{241}Am was blended with Yolo loam (fine-silty, mixed, thermic Typic Xerorthents) to give 14,000 dpm/g soil. The soil was thinly spread out and the ^{241}Am as nitrate applied in a thin film with water. The soil was then carefully transferred to a V blender and mixed for several hours. Quantities of 2000 g were placed into each of six different pots in a glasshouse with natural light and photoperiod. Ten bush bean (Phaseolus vulgaris L. C.V. Improved Tendergreen were grown in each. All received N at 200 μg N/g soil as NH_4NO_3 and soil moisture was kept near -1/3 bar. Half the pots received 100 μg DTPA chelating agent per g soil.

After 14 days the primary leaves were removed. After 7 more days the 1st and 2nd trifoliate leaves were removed. After 14 more days the 3rd and 4th trifoliate leaves were removed. All of these samples were counted individually for each plant by gamma scintillation counting usually for 1 hour each sample.

Results and Discussion

Leaves of plants receiving DTPA contained an order of magnitude or more ^{241}Am than did those not receiving DTPA (Table 1). As observed previously most of the increase for DTPA was in the primary leaves. The coefficient of variation (C.V.) for ^{241}Am in the leaves ranged from 54 to 124% indicative of considerable variability. The C.V. was generally the same for with and without DTPA. The range within each treatment and leaf type was over an order of magnitude (Table 1).

The frequency distributions (Fig. 1 and 2) are highly indicative of log normal distribution. More individuals were in the low count ranges than in the high count ranges. This should be expected from the problem involved in distributing the ^{241}Am among the soil particles.

The C.V. values can be used with the formula (Snedecor, 1946)

$$n = \frac{t^2 \quad CV^2}{d^2}$$

to ascertain numbers of plants needed to assure a given accuracy of assay. To obtain an assured value within 20% of a true mean with 95% confidence of the results and with a C.V. of 60%, 165 plants would be needed. And this is with supposed uniform mixing. The real world is even more variable.

C.R.'s for these data were as previously found for ± DTPA (Wallace et al, submitted). The range, of course, is the same as that for concentration given above, i.e., over an order of magnitude.

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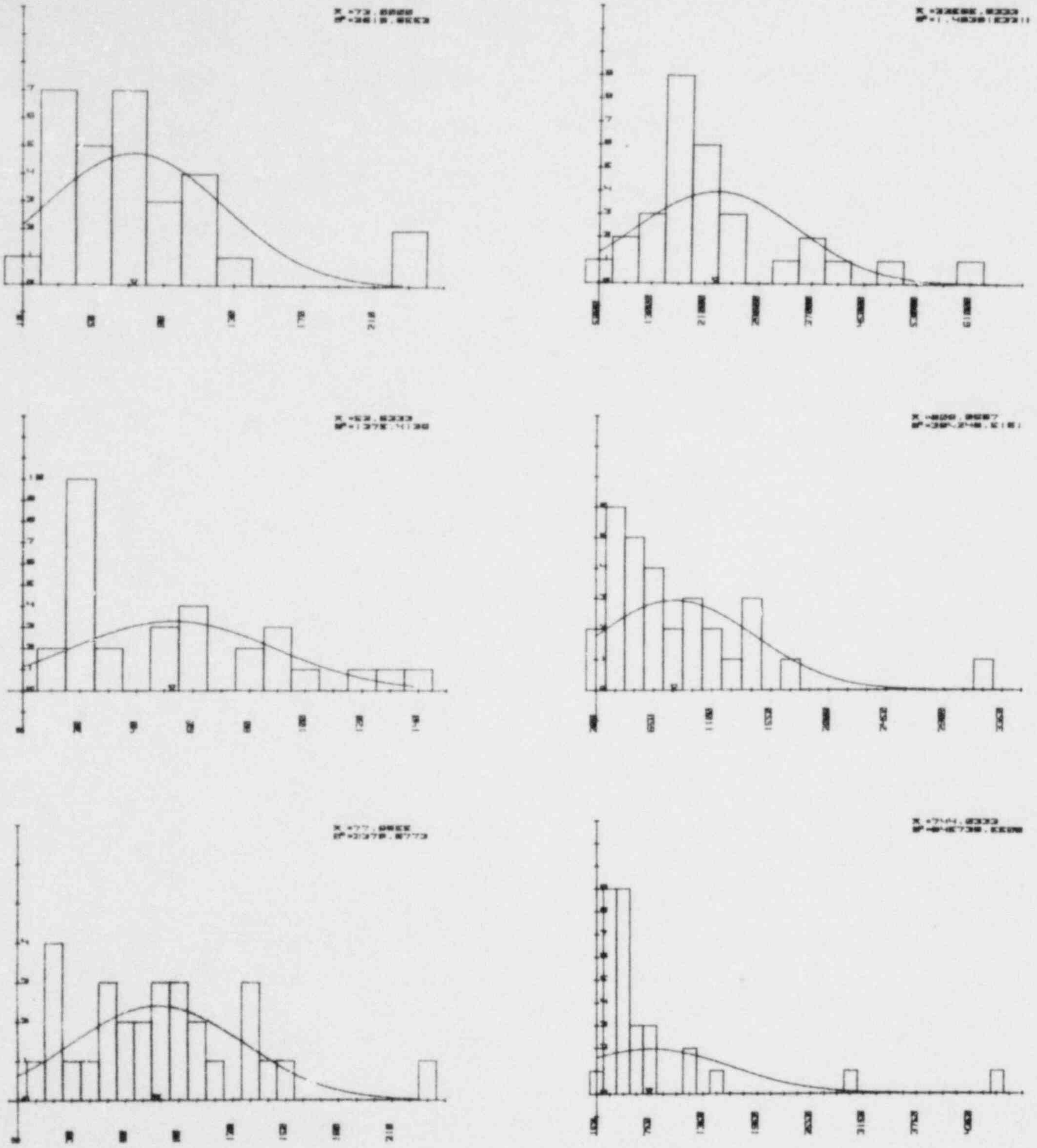

Fig. 1. Frequency distribution on an arithmetic basis for ^{241}Am in bush bean leaves. Left, without chelate; right, with chelate. Top to botton: primary leaf, 1st and 2nd trifoliate leaves, 3rd and 4th trifoliate leaves.

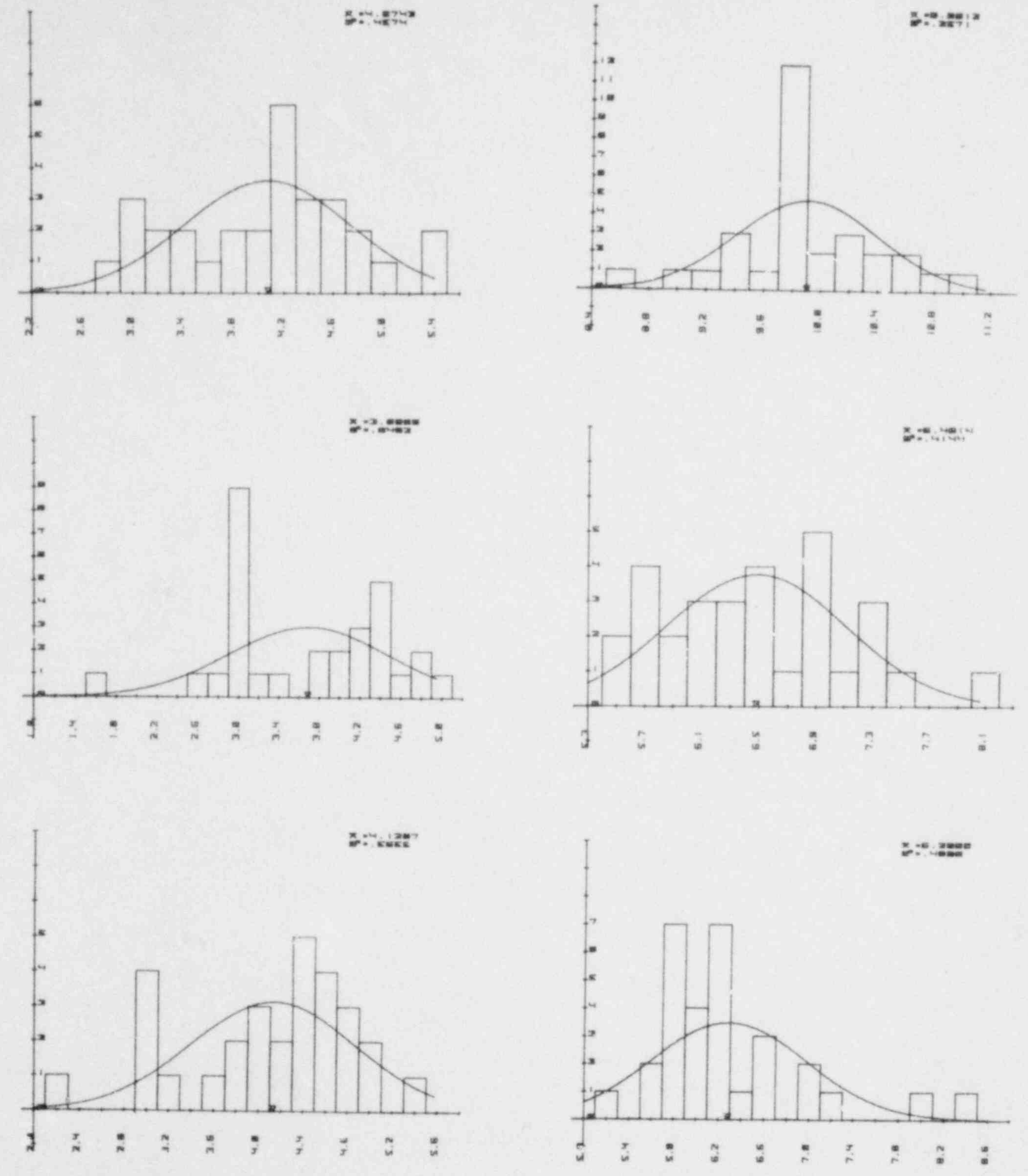

Fig. 2. Frequency distribution on a $\log_e$ basis for ^{241}Am in bush bean leaves. Left, without chelate; right, with chelate. Top to bottom: primary leaf, 1st and 2nd trifoliate leaves, 3rd and 4th trifoliate leaves.

CHELATING AGENTS IN WASTE MANAGEMENT PROBLEMS

The original observations that synthetic chelating agents can mobilize some radionuclides and increase their plant uptake was made in this laboratory. Yttrium was the first element found in this category and eventually the transuranium element americium was also found to be so influenced. Then the same influence was found for plutonium. As yet neptunium, curium, and plutonium have not been evaluated in this respect.

Synthetic chelating agents have a small use in agriculture; perhaps one million acres of the 500 million acres under agriculture in the USA receive some kind of chelate application. Since it has been concluded that the levels used will not increase plant uptake by more than one order of magnitude, the leaders of the Biology and Environmental Group of the Department of Energy have decided that no problem exists.

Shallow burial waste storage of radionuclides presents other problems, however. Many of the buried wastes contain synthetic chelating agents which were used in industrial processes or in cleanup operations. In many cases in the burial trenches there has been no chance for any type of degradation of them and they are still available for facilitating transport through soils or to plants. It should also be emphasized that many naturally produced organic compounds have chelating ability.

Generally overlooked in the evaluation of chelating agent effect is the concentration of them. It is never safe to conclude that chelating agent effects can be generalized to one order of magnitude. Depending on concentration their effects can be more than an order of magnitude. This is illustrated in the short report which follows.

EFFECT OF VARYING CONCENTRATIONS OF DTPA CHELATING AGENT ON UPTAKE AND DISTRIBUTION OF ^{241}Am IN BUSH BEAN PLANTS GROWN IN SOIL

Abstract: Bush bean plants (Phaseolus vulgaris L. CV Improved Tendergreen) were grown in pots containing Yolo loam soil in a glasshouse for 15 days with a uniformly applied level of ^{241}Am in soil (14,000 dpm/g soil) and with varying concentrations of DTPA applied to the soil. The objective was to demonstrate that the effects assigned to this chelating agent on uptake of ^{241}Am by plants will vary with concentration of the chelating agent. Under some waste-management conditions this could be of importance. On a concentration basis, the DTPA resulted in transport of much more ^{241}Am into primary leaves than into trifoliate leaves. The ratio of ^{241}Am in primary leaves to that in trifoliate leaves increased with increasing concentration of DTPA. The concentration ratios in each plant part tended to increase with increasing DTPA. Without DTPA they were around 3×10^{-2} for these young plants.

Introduction

Chelating agents, particularly DTPA (diethylene triamine pentaacetate), have the ability to promote plant uptake of at least some actinides (Adriano et al. 1977; Francis, 1973; Romney et al. 1970; Wallace, 1972). Some experiments have revealed relatively little effect and others have indicated much larger effects. Some differences, of course, are related to soil pH, plant species and other factors (Francis 1973). Perhaps the greatest factor which can be involved may be that of concentration of chelating agent; yet no experiments have been reported relating to this matter.

There is probably relatively little problem associated with concentration of chelating agents used in agriculture to correct micronutrient deficiencies. The concentrations used in agriculture probably vary only by a factor of 2 to 3. In shallow burial waste management situations in which concentration of chelating agent can vary several fold, there is a much greater danger to promoting actinide transfer to the food chain. That, of course, is only in the limited situations where such products are stored.

Materials and Methods

Yolo loam soil (fine-silty, mixed, thermic Typic Xerorthents) was blended with ^{241}Am (as nitrate) to give 14,000 dpm/g soil. Bush bean plants (Phaseolus vulgaris L. CV Improved Tendergreen) were grown in 500 g quantities of this soil in a glasshouse with natural lighting and photoperiod. There were two plants per pot with triplicate pots per treatment with 0, 50, 100, 200 and 500 μg DTPA added per g of soil. The DTPA was applied as the Na salt. Nitrogen was applied at the rate of 200 μg N per g soil. Soil moisture was kept near -1/3 bar. Plants were harvested after 15 days by cutting two cm above the soil line and separated to primary leaves, trifoliate leaves and stems.

The purpose of the experiment was not to determine concentration of ^{241}Am which might pass to the food chain but rather to determine relative effects of different concentrations of DTPA on uptake to plants and its distribution in vegetative parts of plants. For this reason no attempt was made to grow the plants to the seed production stage at this time.

Results and Discussion

The concentration of ^{241}Am increased generally in the plant parts analyzed with increase of applied DTPA (Table 1). The primary leaves (first two leaves formed from cotyledon) especially at the highest level of DTPA contained far more ^{241}Am than did the trifoliate leaves and stems. The ratio of ^{241}Am in primary leaves to that in trifoliate leaves increased considerably with increased DTPA indicating preferential transport of the ^{241}Am with DTPA to primary leaves. This may indicate that the chelate problem is less than anticipated.

The argument as to whether or not the chelating agent is absorbed with the ^{241}Am was discussed previously (Wallace et al. submitted). If chelate were present in the primary leaves with the ^{241}Am on an equivalent basis, less than 0.01 µg DTPA/g leaf need be present. From all past experiences this is easily possible even though plants reject the majority of chelate.

It would appear, at least in these young plants, that there is a channel via xylem elements to the primary leaves through which the ^{241}Am (chelated) preferentially moves. This would have the advantage of not having ^{241}Am move into the food chain. Previous work had shown that ^{241}Am is not easily retranslocated from old leaves to new growth.

Without chelating agents, the concentration ratios (C.R.) were about 3×10^{-2}. This is in the generally accepted range for this element (Schulz 1977). With DTPA the C.R.'s increased but the greatest was for 500 µg DTPA per g soil.

The specialized effects of synthetic chelating agents may not be a major factor in the environmental hazards assessment of ^{241}Am and other actinides but they may be indicative of what natural soil chelators can do but on a smaller scale (Francis, 1973). Since synthetic chelating agents are used in agriculture and since synthetic chelating agents are used for washing and extracting in the nuclear industries, their effects on biological transport of actinide metals must be understood.

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Table 1. Effect of different concentrations of DTPA on uptake and distribution of ^{241}Am in bush bean plants grown in soil.

DTPA	Primary Leaves	Trifoliate Leaves	Stems	$PL/_{TL}$	$TL/_{S}$
µg/g Soil	dpm/g dry wt			ratio	
0	415	552	327	0.80	1.60
50	1893	876	850	2.16	1.11
100	2274	947	850	2.33	1.03
200	2912	469	460	6.21	1.02
500	29956	1840	2079	16.28	0.88
F value	3.2**	8.8**	4.4**	-	-
LSD 0.05	1672	85	95	-	-
		C.R.			
0	0.030	0.038	0.023	-	-
50	0.135	0.063	0.061	-	-
100	0.162	0.068	0.061	-	-
200	0.208	0.034	0.033	-	-
500	2.14	0.131	0.150	-	-

GENERALIZED CONCENTRATION RATIOS FOR PLUTONIUM UPTAKE BY PLANTS FROM SOIL

At the Arlie, Virginia workshop held October 10-12, 1978 under sponsorship of the Department of Energy, it was concluded that synthesis and generalization of the available data were highly important in being able to move forward with nuclear energy plans.

Concentration ratios* (CR) have been developed under many experimental conditions for reasons of prediction of uptakes where only soil concentration is known. The result has been that the ratios vary widely--even over several orders of magnitude. It is possible, however, to make some generalizations from the factors which result in the variability. The workshop wanted to adopt a simple 2 x 2 set of values but we feel that the following 2 x 3 set of CR's more closely fits plants in general for plutonium:

Plant Part	Clay Content of Soil Low	Clay Content of Soil High
Soil pH <<5.5		
Seeds	10^{-3}	10^{-4}
Whole Plant	10^{-2}	10^{-3}
Soil pH 5.5 - 7.0		
Seeds	10^{-4}	10^{-5}
Whole Plant	10^{-3}	10^{-4}
Soil pH >>7.0		
Seeds	10^{-5}	10^{-6}
Whole Plant	10^{-4}	10^{-5}

In this scheme of three pH values and two levels of clay the C.R.'s are suggested to range over three orders of magnitude for a given plant part and that fruits or seeds are a magnitude lower than vegetation.

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* CR is the ratio of actinide element in a plant or plant part to that in soil.

It is recognized that each value can easily be off by an order of magnitude and that the presence of a synthetic chelating agent especially under waste management conditions can increase the C.R.'s by at least an order of magnitude depending on concentrations of both chelating agent and plutonium.

EXTRACTABILITY OF TRANSURANIC ELEMENTS IN SOILS

The objectives of this project are to determine the chemical extractability of transuranic elements in different kinds of soils, to determine the factors influencing the extractability, and to correlate chemical extractability with biological availability. Work on this project was initiated during the latter part of FY 1978.

Extractability was determined by an equilibrium batch technique. Five-g aliquots of contaminated soils (oven-dry basis) were suspended in 25 ml of extracting solution in polypropylene centrifuge tubes and allowed to reach equilibrium for 72 h with continuous mixing. After the equilibration period, the suspensions were centrifuged at 17,369 gravity for 15 min. to separate the liquid from the solid phase. Each soil was extracted in triplicate. The radionuclides in the supernatant liquid is called the "extractable" fraction.

The results obtained to date using 0.05 M $CaCl_2$ as the extraction solution are shown in Table 1. The percentage of extractable radionuclide for Egbert muck (45.2 percent organic matter) was consistently the lowest among the soils examined. Among the remaining soils, the radionuclide extractability for Yolo and Aiken soils was consistently lower than for Malbis, Sharpsburg, and Lyman soils. The extractability from the Nebraska soil (Sharpsburg) was consistently lower than that from Malbis and Lyman soils.

This study is important to the evaluation of the plant uptake studies being completed and to the modeling aspects of those studies.

Table 1. Extractability of $^{237}N_{p}$, $^{239,240}Pu$, ^{241}Am, and ^{244}Cm by 0.05 M Ca Cl_2.

		^{237}Np			$^{239,240}Pu$			^{241}Am		
Soil Series	Soil extract pH	Soil Activity d/m/g	Extractable d/m/g	Extractable %*	Soil Activity d/m/g	Extractable d/m/g	Extractable %*	Soil Activity d/m/g	Extractable d/m/g	Extractable %*
		$X10^2$			$X10^4$			$X10^3$		
Egbert	6.68	11.9	9.00	0.76	11.9	27.95	0.02	11.9	5.59	0.05
Holtville	7.49	5.5	16.40	2.98	5.5	62.80	0.11	5.5	4.83	0.09
Yolo	6.23	6.3	44.50	7.06	6.3	27.28	0.04	6.3	4.53	0.07
Aiken	5.05	7.8	90.50	11.60	7.8	31.43	0.04	7.8	8.3	0.10
Malbis	5.68	6.2	77.00	12.42	6.2	57.09	0.09	6.2	7.97	0.13
Sharpsburg	5.09	6.8	142.50	20.96	6.8	50.34	0.07	6.8	7.73	0.11
Lyman	4.64	7.1	157.70	22.21	7.1	59.2	0.08	7.1	20.60	0.29

*Percent of soil activity (dose).

RADIOCHEMICAL DETERMINATION OF NEPTUNIUM-237, PLUTONIUM-238, PLUTONIUM-239,240, AMERICIUM-241, AND CURIUM-244 IN PLANT MATERIAL

In order to carry out the objectives of this project it is necessary to determine the concentration of ^{237}Np, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and ^{244}Cm in plant material where these isotopes are all present in one sample and in low concentrations. Since, by the nature of this research, the plant samples may be limited in size, it is also necessary that any separation process be sequential and compatible so that the entire amount of each isotope can be utilized in alpha pulse height analyses, if necessary. That is, the procedure must be such that it would not be necessary to split the plant sample for separate use in determination of the various actinides. Initially, it was thought that one of the existing published procedures could be utilized, but for one reason or another, the several procedures that were tried were found to be less than satisfactory. After rather extensive trials, a suitable analytical procedure has been developed for use at U.C. Berkeley. This report states the highlights of the development of the procedure and the resulting analytical procedure is given in detail.

One of the first methods tried was a combination of an anion exchange column procedure(4,5) followed by Dibutyl N, N-diethylcarbamylphosphate (DDCP) separatory extraction.(2) This procedure was judged to be unsatisfactory due to incomplete removal of Np from the column, thus affecting the separation between Np and Pu. This was observed experimentally in our laboratory with approximately 65% of the Np remaining on the column. A similar finding has been reported by Campbell and W. P. Moss.(3) The

DDCP separatory extraction proved inefficient in removal of unwanted other salts, such as those of iron, and this led to a degradation of the Am and Cm spectrum during alpha-spectrometric pulse height analysis. In addition, the DDCP method inherently causes phosphate residues to appear on the electrodeposition plates; this interferes with the pulse-height determination as documented by F.E. Butler and R. M. Hall.(2)

The second method tried essentially consisted of scavenging by coprecipitation with $Fe(OH)_3$ followed by a cation exchange column purification procedure.(7) We had several reasons for not adopting this procedure. First, the procedure limits the amount (weight in grams) of ashed material which can be analyzed; this is illustrated in Table 1, where it is seen that actinide recovery decreased with increasing sample size. Also, Americium and Curium are chemically very similar and therefore should trace one another. As seen in Table 1, however, the ^{244}Cm is either masked or lost to a greater extent than the ^{241}Am. Table 1 also shows that ^{237}Np recovery may vary as much as 20% (98-78%) by this method. Secondly, the five fractions (^{237}Np, ^{238}Pu, ^{239,240}Pu, ^{241}Am, and ^{244}Cm) were plated on the <u>same</u> disc; thus there is some difficulty in differentiating between the tailing edge and the leading edge of each element. This is exemplified in Table 2, channels 296-300. In the interpolation of the spectrum, if one additional channel is chosen as the end of the tailing edge (i.e. 298 instead of 297), then this will change the recovery by 2-3%. This is troublesome only because an irregular pattern is involved In other words, the next time a sample is counted the difficult channels may be 300-304. This method, therefore, is inconsistent when all four elements are plated on <u>one</u> disc. Thirdly, there is no resolution between

TABLE 1: Scavenging Followed by Cation Exchange

Sample No.	Type of Material	Weight of Dry Plant Material	Residue Weight After Ashing at 550°C	Wet Weight After Final Co-ppt with $Fe(OH)_3$	Recovery			
					237 Np	239/240 Pu	241 Am	244 Cm
		grams	grams	grams	------------%-----------			
44-52a	alfalfa	1.0	0.08	0.29	98	101	82	64
44-52b	alfalfa	1.0	0.08	0.37	98	104	78	62
44-53a	alfalfa	1.0	0.08	0.35	84	100	74	55
44-53b	alfalfa	1.0	0.08	0.35	88	103	84	74
45-03a	straw	3.2	0.38	0.65	85	79	48	32
45-03b	straw	3.2	0.38	0.58	78	101	58	41

TABLE 2: COUNTS PER CHANNEL FOR ^{237}Np, ^{238}Pu, ^{239,240}Pu, ^{241}Am, ^{244}Cm

Channel	Counts	(Ident.)	Channel	Counts	(Ident.)	Channel	Counts	(Ident.)
		meV			meV			meV
256	1		286	600		316	466	
257	34		287	620		317	554	
258	26		288	681		318	667	
259	31		289	933		319	772	
260	36		290	1572		320	1058	
261	38		291	2376	(^{237}Np=4.79)	321	1732	(^{241}Am=5.48)
262	38		292	2336		322	2462	
263	42		293	1296		323	3249	(^{238}Pu=5.50)
264	35		294	692		324	2509	
265	53		295	387		325	749	
266	53		296	284		326	300	
267	45		297	240		327	273	
268	52		298	241		328	305	
269	68		299	264		329	314	
270	73		300	326		330	366	
271	70		301	350		331	469	
272	88		302	437		332	528	
273	74		303	538		333	697	
274	110		304	706		334	940	
275	114		305	1178		335	1394	
276	109		306	1784		336	1910	(^{244}Cm=5.81)
277	125		307	2864		337	2407	
278	133		308	4167	(^{239,240}Pu= 5.16)	338	1804	
279	156		309	2945		339	274	
280	200		310	638		340	3	
281	201		311	265		341	0	
282	239		312	286		342	0	
283	348		313	327		343	0	
284	413		314	273		344	0	
285	567		315	355		345	0	

the spectra of ^{238}Pu and ^{241}Am because the pulse-energies are too close together (^{238}Pu = 5.499 mev and ^{241}Am = 5.477 mev. For further documentation of this, see Table 2, channels 319-326).

Next, an attempt was made to modify the plutonium-neptunium-uranium method of Butler(2) to include Am and Cm. This procedure basically is a tri-isooctylamine (TIOA) separatory extraction with the Am/Cm fraction also containing the majority of unwanted ions. Therefore, a modified procedure of scavenging by co-precipitation coupled together with a cation exchange column purification(7) was used to remove these ions from the Am/Cm fraction. The results of this procedure showed improvement over previous procedures. There were, however, some limitations concerning the amount (weight in grams) of ashed residue from plant material that could be analyzed (Table 3). Again, in some cases the ^{244}Cm and the ^{241}Am did not trace well. The ^{237}Np inconsistently decreased with the amount (weight in grams) of ashed plant material that was being analyzed.

Additional work showed that as the size of the sample increased further, both the actinide yield and the efficiency of separation decreased sharply. For example, as the size of the sample was increased to 20 grams of dry plant material, a large proportion of the Np was found in the Pu and Am/Cm fractions. To get around this problem, scavenging of the actinides with $Fe(OH)_3$ from a large solution volume was carried out to remove the bulk of the interfering salts. This step was carried out just prior to the TIOA extraction procedure. The $Fe(OH)_3$ precipitate was recovered by filtration on paper, then re-ashed. The addition of this step significantly improved the amount of ashed residue from plant material which could be analyzed. It was also found that as the size of the plant sample was increased and

TABLE 3: LIMITATIONS OF MODIFIED PROCEDURE

Sample No.	Type of Material	Weight of Dry Plant Sample	Weight After Ashing at 550°C	Wet Weight of Am/Cm Frac After CO-ppt with $Fe(OH)_3$	Recovery 237 Np	Recovery 238 Pu	Recovery 239/240 Pu	Recovery 241 Am	Recovery 244 Cm
		grams	grams	grams					
49-55-5a	wheat/straw	0.5	.08	.42	94	96	90	104	106
49-55-5b	wheat/straw	0.5	.09	.43	101	86	102	94	105
49-55-1a	wheat/straw	1.0	.16	.43	91	101	107	108	97
49-55-1b	wheat/straw	1.0	.16	.39	78	95	93	104	101
49-55-2a	wheat/straw	2.0	.32	.41	61	98	94	49	47
49-55-2b	wheat/straw	2.0	.32	.48	86	94	99	56	58
49-55-3a	wheat/straw	3.0	.47	.43	67	90	87	82	59
49-55-3b	wheat/straw	3.0	.47	.50	74	77	87	60	56
50-01-1b	alfalfa	1.0	.07	.46	94	94	97	102	102
50-01-2b	alfalfa	2.0	.14	.46	-	76	96	96	98
50-01-3a	alfalfa	3.0	.22	.43	81	90	99	95	98
50-01-4a	alfalfa	4.0	.29	.51	62	64	100	96	98
47-57-2	alfalfa	5.0	.34	.74	73	78	78	27	22

when the $Fe(OH)_3$ pre-precipitation step was initiated, it became necessary to remove residual salts from the Np and Pu fractions by means of the cation column procedure. Inclusion of these modifications led to the results obtained in Table 4. There still remained a problem in obtaining adequate recovery of Np, Am, and Cm. It is seen in Table 4 that the weight of the wet $Fe(OH)_3$ precipatate after the final washing during the removal process of extraneous salts from the Am/Cm fraction was inversly proportioned to the percentage of Cm and Am recovered. Further experimentation indicated that repeated $Fe(OH)_3$ scavenging of the Am/Cm fraction is required to remove excess salts. Table 4 also indicates Np recoveries in the range of 70-80%. The loss of Np was investigated and found to occur in the cation exchange column procedure (Table 5). As the loss of Np is a procedural loss and can be modified only slightly (i.e., by excluding the 8 ml 1.5N HCL step), the decision was made that the best solution would be to use tracing methods to correct for yield in the Np analyses.

The preceding work also indicated that there was always the possibility of low yields in the chemical separation and purification processes, therefore, tracer techniques were adopted for the entire analytical procedure. ^{242}Pu was incorporated as the tracer for ^{238}Pu and $^{239,240}Pu$. ^{243}Am was selected as the tracer for ^{241}Am and ^{244}Cm. ^{239}Np was chosen as the tracer for ^{237}Np. The short lived ($T_{\frac{1}{2}}$ = 2.35 days) ^{239}Np is obtained from the ^{243}Am parent by means of the TIOA extraction. It is to be noted that the ^{239}Np daughter of ^{243}Am is always added along with the ^{243}Am tracer and this additional ^{239}Np must be taken into account.

The above work, plus additional "spot trials" led to the formulation of a general procedure. The procedure is described below in detail. The

TABLE 4: MODIFICATION OF PROCEDURE TO REMOVE THE MAJORITY OF ALKALINE EARTHS BY GRAVITY FILTRATION

Sample No.	Type of Material	Weight of Sample, Dry Plant Material	Weight After Ashing at 550°C	Wet Weight of Am/Cm Frac After $Fe(OH)_3$ Co-ppt and Washing	Recovery 237 Np	238 Pu	239/240 Pu	241 Am	244 Cm
		grams	grams	grams	%				
49-58	wheat/straw	20.0	2.39	.30	71	92	94	98	97
54-63	wheat/straw	20.0	2.34	.38	76	96	98	87	85
55-68	wheat/straw	20.0	2.68	.52	74	96	97	60	62
51-56	alfalfa	20.0	1.49	.49	71	102	100	68	67
51-58	alfalfa	20.0	1.47	.44	78	102	100	97	105

TABLE 5: EXAMINATION OF COLUMN ELUATES DURING CATION EXCHANGE COLUMN PROCEDURE

Sample No.	Eluate Fraction	Estimated ^{237}Np loss
		-----%----
54-65	20 ml NH_2OH/HCl	4.8
54-65	50 ml 0.1 N HCl	-
54-65	25 ml 1.0 N HCl	5.1
54-65	50 ml 0.1 N HCl in CH_3OH	.8
54-65	25 ml 1.0 N HCl in CH_3OH	3.0
54-65	8 ml 1.5 N HCl	8.0

TABLE 7: RESULT OF PRESENT PROCEDURE USING TRACING TECHNIQUES

Sample No.	Type of Material	Weight of Sample	Weight After Ashing	Weight of Am/Cm Frac After co-ppt	Recovery							
					237 Np	239* Np	238 Pu	239/240 Pu	242* Pu	241 Am	243* Am	244 Cm
		grams	grams	grams	%							
52-59	alfalfa	20.0	1.47	.37	87	84	95	94	93	104	106	104
52-61	alfalfa	20.0	1.48	.36	93	85	99	98	99	108	109	102
58-75	wheat/grain	20.0	0.33	.36	68	66	93	93	90	102	102	102
58-76	wheat/grain	20.0	0.33	.37	79	72	101	97	96	104	104	100
56-55	wheat/straw	20.0	2.24	.29	91	89	94	92	94	102	102	99
56-57	wheat/straw	20.0	2.20	.31	84	84	92	92	90	96	100	97

*Tracers

method was tested by adding all of the isotopes, including the tracers to ashed wheat grain, straw, and alfalfa samples, then analyzing the samples per the procedure. The results are given in Table 7. All Pu, Cm, and Am isotope yields, including the tracers, were greater than 90%. The yield of each isotope of the same element agreed well. The Np yields ranged from 66 to 91%, but the yields of both ^{237}Np and tracer ^{239}Np were similar, indicating the validity of this tracer technique.

This procedure is now being utilized for analyses of plant material obtained in the plant uptake experiments described in the following sections of this report.

PROCEDURE

Dry Ashing

1. Weigh dry plant material into pyrex beaker, place in muffle furnace and bring temperature slowly to 550°C.
2. Maintain 550°C overnight (15-24 hours), then cool sample to room temperature.

Wet Digestion

3. Transfer sample to 100 ml Teflon beaker using 8 N HNO_3; evaporate to dryness.
4. Add radioactive tracers to samples; evaporate to dryness.
5. Add 10 ml 16 N HNO_3, 10 ml 48% HF and 5 ml 70% $HClO_4$ to sample.
6. Evaporate sample to dryness using an aluminum block (Note One). Constant boiling temperature of $HF/HClO_4$ = 203°C, therefore, temperature of said block should be approximately 225°C.
7. Cool to room temperature.
8. Repeat steps 5, 6, and 7.

Major Removal of Alkaline Earths

9. Transfer sample to 600 ml beaker using 3 N HNO_3; bring volume to 300 ml.
10. Add 1 ml Fe^{+3} carrier solution (Note Two)
11. Co-precipitate actinides with $Fe(OH)_3$ using concentrated NH_4OH; bring p^H to 8.
12. Heat on hot plate for approximately 45-60 minutes allowing precipitate to form.
13. Cool to room temperature.
14. Filter, by Gravity Filtration, through #42 Whatman filter paper.
15. Rinse with three minimum volume portions of 1:20 NH_4OH solution.
16. Transfer to original beaker.

Reashing

17. Dry the filter sample, including the filter paper, at 100°C for one hour.

18. Place sample in muffle furnace.

19. Slowly bring temperature to 550°C.

20. Maintain temperature of 550°C for 8 hours.

21. Cool to room temperature.

22. Transfer to Teflon beaker, previously used in step 3 using 8 N HNO_3.

23. Add 10 ml 48% HF and 5 ml 70% $HClO_4$; evaporate to dryness using the aluminum block (Note One).

24. Cool to room temperature.

Separation of Actinides

Steps 25-36 are adapted from Butler(2). It should be noted from the reference that this procedure could include uranium analysis.

25. Dissolve sample in 50 ml 8 N HCl, heating slightly.

26. Pour the solution into a 125 ml separatory funnel.

27. Rinse this Teflon beaker using three 10 ml portions of 8 N HCl; add these portions to the separatory funnel.

28. Add 10 drops 30% H_2O_2; invert separatory funnel a few times.

29. Add 25 ml 10% TIOA-xylene to the separatory funnel; shake vigorously for 10 seconds and drain the lower aqueous phase into a 250 ml beaker (this is the Am/Cm fraction to be used in a later determination, see Note Three).

30. Rinse the organic phase with 25 ml 8 N HCl, shake again for 10 seconds, drain lower aqueous phase into the same 250 ml beaker as in the previous step.

31. Add 25 ml 8 N HCl/0.05 N NH_4I (50-80°C, shake for 1 minute, release pressure after 5 seconds (this reduces the Pu from IV to III, see Note Four).

32. Drain the lower aqueous phase into a 100 ml beaker; save for

Pu determination.

33. Repeat steps 31 and 32.

34. Add 25 ml 4 N HCl/0.02 N HF; shake for 10 seconds.

35. Drain lower aqueous phase into a 100 ml beaker; save for Np determination.

36. Repeat steps 34 and 35.

Purification of Americium/Curium Fraction by $Fe(OH)_3$ Precipitation

Steps 37-61 are adapted with modification from Wood, et al(7).

37. Evaporate Am/Cm fraction to dryness.

38. Add 10 ml 16 N HNO_3 to the sample, digest for 1 hour and evaporate to dryness.

39. Transfer to 50 Teflon centrifuge tubes using 1 N HNO_3 in four 5 ml portions.

40. Add 10 mg Fe^{+3} carrier solution.

41. Add 10 ml hot 4 N NaOH; heat in hot water bath for 30 minutes.

42. Centrifuge at 10,000 x g for 5 minutes; discard the supernatant liquid.

43. Wash the precipitate with approximately 20 ml distilled water to remove any trace NaOH, centrifuge 10 minutes and discard supernatant.

44. Dissolve the precipitate using 1 ml 16 N HNO_3; dilute to 20 ml by adding water.

45. Add concentrated NH_4OH until the pH = 8; heat in hot water bath.

46. Centrifuge 5 minutes; discard supernatant.

47. Wash precipitate with 20 ml water, centrifuge 10 minutes and discard supernatant.

48. Repeat steps 44, 41, 42, and 43 respectively (from 43 go to step 49).

49. If weight of wet precipitate is 0.35 grams or lower, proceed further; if it is not, then follow routine as in above steps.

As an additional guide for completeness of salt removal, the color of the gelatinous precipitate should be red-brown at the end of both steps 47 and 48. If not, repeat steps 44 through 48 inclusive, so as to obtain the red-brown $Fe(OH)_3$ color at the end of both steps.

Reduction of Fe^{+3} Carrier

50. Add 10 ml NH_2OH/HCl to each of the three fractions, Np, Pu, and Am/Cm; heat in a hot water bath for 20 minutes or until the brownish color of iron disappears (Note Five).

51. Add another 10 ml portion NH_2OH/HCl; heat 20 minutes more.

52. Allow to stand 1 hour or overnight.

Adsorption on Cation Exchange Column

53. Prepare exchange column by weighing out 1.30 grams AG 50W-X4 cation exchange resin; load into jacketed columns and place a glass wool plug at the top of the resin in the column (Note Six).

54. Run water (50°C) through outer jacket of the column.

55. Transfer the solution from step 52 into the column.

Elimination of Extraneous Ions

56. Add 50 ml 0.1 N HCl to original centrifuge tubes; pour into respective columns and discard eluate.

57. Repeat step 56 using 25 ml 1.0 N HCl.

58. Add 50 ml 0.1 N HCl in CH_3OH; discard eluate (Note Seven).

59. Repeat step 58 using 25 ml 1.0 N HCl in CH_3OH; discard eluate.

60. Add 8 ml 1.5 N HCl to the columns containing Am/Cm and Pu fractions. Omit this step for Np determination (Note Eight).

61. Add 40 ml 12 N HCl to the column; elute sample into 150 ml beaker.

Electrodeposition

See references 4, 6.

62. Evaporate sample to dryness.

63. Add 5 ml 16 N HNO_3 and 0.5 ml 36 N H_2SO_4; heat on hot plate to evaporate the HNO_3, leaving behind only the H_2SO_4 (Note Nine).

64. Cool to room temperature; add 3 ml water.

65. Add 2 drops 0.4% thymol blue indicator.

66. Neutralize until pH 2 end point is reached by blowing gaseous NH_3 over the surface of the samples while swirling (Note Ten).

67. Pour into electrodeposition cells; rinse beaker several times using a total of 6 ml 0.36 N H_2SO_4 (Note Eleven).

68. Again, blow NH_3 gas over the surface to obtain a pH 2 end point, if end point is passed, add 0.36 N H_2SO_4 dropwise until pH = 2.

69. Electrodeposit the sample on a stainless steel disc using a current of 300 mA for a period of six hours (Note Twelve).

70. Add 10 ml 1.5 N NH_4OH; continue current flow for 1 minute, then remove from apparatus, discard and rinse three times using 0.15 N NH_4OH in a 10% NH_4NO_3 solution. Rinse disc with EtOH adjusted to pH 8 with NH_4OH.

71. Place stainless steel disc on hot plate (350°C) for 1 minute.

72. Cool, then count (Note Fourteen).

NOTES

Note One: Aluminum block was constructed by using a 31cm X 31cm X 5.3cm aluminum block and boring 16 uniformly placed holes measuring 52.8mm in diameter through the block. An additional aluminum plate measuring 31cm X 31cm X 2.5cm was fastened to the bottom of the first block using fillister screwhead bolts. The block was then wrapped with 3 inch fiberglass insulation and self-adhesive, one-piece foam/foil pipe insulation to minimize heat loss. The aluminum block apparatus was used in conjunction with Sybron Thermolyne Type 2200 hot plate and a system of 4 250 watt heating bulbs approximately 30cm above the top of the aluminum block.

Note Two: One ml Fe^{+3} carrier solution contained 10 mg Fe as $Fe(NO_3)_3$.

Note Three: Preparation of TIOA-xylene Carrier

1. Add in a ratio of 9:1 xylene/TIOA (Tri-isooctylamine) to a separatory funnel
2. Add 1/2 the volume of step 1 of 0.1 N HCl, shake for 10 seconds, allow time for separation and discard lower aqueous phase
3. Repeat Step 2
4. Add 1/2 the volume of distilled water in step 1, shake for 10 seconds, allow time for separation and discard lower aqueous phase

Note Four: The 8 N HCl/0.05 N NH_4I solution should be made just prior to use.

Note Five: Preparation of NH_2OH/HCl is as follows:

1. Dissolve 6.95 gm Hydroxylamine Hydrochloride into 800 ml water.
2. Add 8.33 ml 12 N HCl; adjust volume until one liter.

Note Six: The columns used were o.7cm I.D. by 15 cm in length (Bio-Rad Laboratories #737-1231). The wet resin column height of the 100-200 mesh resin was approximately 5cm.

Note Seven: The 0.1 N HCl in CH_3OH was prepared by:

1. Placing 8.33 ml concentrated HCl in anhydrous methyl alcohol to one liter.

The 1.0 N HCl in CH_3OH was likewise prepared by:

1. Using 83.3 ml concentrated HCl in anhydrous methyl alcohol.

Note Eight: It was observed that the 1.5 N HCl (8 ml) eluted Np from the column hence led to low yields, thus it is left out on that particular fraction (Np) only. Little salt is present in the Np fraction as removed from the TIOA and the 1.5 N HCl wash is not required. However, this step cannot be ommitted from the Am/Cm fraction as significant salt remains at this point.

Note Nine: The 5 ml 16 N HNO_3 is used to dissolve any residue that may remain. Once the HNO_3 has volatilized, any fumes which appear indicate the end point.

Note Ten: The gaseous ammonia is obtained from a polyethylene wash-bottle that has the inner portion of the delivery tube removed and contains concentrated NH_4OH to a volume of one-third of the polyethylene bottle.

Note Eleven: The electrodeposition cell is constructed as follows: Using a 30 ml linear polyethylene bottle (catalog #2C02-0001 from Sybron/Nalge Co., Rochester, NY 14525), cut the bottom off with a razor blade and discard the cap. Using a plating cell cap (# J-604 from Control Molding Corporation, Staten Island, NY 10303), place a stainless steel disc (1.75 cm in diameter) into the cap. A rubber O-ring gasket (obtained from Bearing Specialty, 12750 San Pablo Avenue, Richmond, Ca: part #A-112) is placed on top of the stainless steel disc. This assembly is then joined to the bottle. The linear polyethylene bottle is cleaned before use with chromic acid cleaning solution. The stainless steel disc and the O-ring are also cleaned in this manner, but only briefly so as to prevent the rubber from becoming brittle. See reference(4)

Note Twelve: A 7.5 V, 10 A power supply (furnished by Heath, model-sp 3730) was used as a power source. The electrodeposition apparatus was set up in a parallel fashion along a flex-rod ladder formation, in which the cathode (a stainless steel disc) was movable along a vertical plane beneath the anode. Using 6 V constant, the current was controlled by use of a 5 ohm variable potentiometer. The platinum wire used was 22 gauge and the stainless steel disc was 1.75 cm in diameter with one side polished.

Note Thirteen: The 0.15 N NH_4OH/10% NH_4NO_3 solution is prepared as follows:

1. Dissolve 100 grams NH_4NO_3 in 500 ml distilled water.
2. Add 10 ml NH_4OH and bring volume to one-liter.

Note Fourteen: The alpha spectrometry counting system is comprised of four Canbera vacuum chambers (Model 7400) with partially depleted surface barrier detectors, each having an area of 300 mm^2, 25 keV, full width, half maximum alpha resolution and 100 micron depletion depth (Canbera Model No. PD 300-25-100). A Canbera Model 3001, Bias Voltage Supply, provides 100 volts to the detector. The Preamplifier is a Canbera Model 970D. The amplifier is a Canbera 1416B. The mixer-router is a Tracor Northern (Model NS 459). The multi-chamber analyzer is a Tracer Northern NS 900. The active disc area is 133 mm^2 and is located 8.6 mm below the detector. The efficiency of the system is about 13%. Samples are counted in a gas pressure of ten millitorr.

The beta counting equipment is made up of a Tracerlab Model SC-78 Compumatic ii Spectrometer, FD-2 Flow Counter, having a 2 inch Mono/Mol Window Assembly, aluminum-coated 200 $\mu g/cm^2$. The gas used is 99.05% Helium and 0.95%

Isobutane. The distance between the window and plated disc is 5 mm. Two sheets of one mil mylar film is used as an absorber to stop the alpha particles. As SC-100 Multimatic Sample Changer is used up to 50 samples in sequence. An SC-88 Auto/Computer is used to print out the count data on paper tape.

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PLANT UPTAKE OF TRANSURANIC ELEMENTS FROM SEVEN SOILS

The objective of this experiment was to study the uptake of ^{237}Np, ^{239,240}Pu, ^{241}Am, and ^{244}Cm by wheat from seven different soils. INIA 66R wheat was grown on the following soils: four from California - (1) Yolo (2) Egbert (3) Aiken (4) Holtville and three from other states - (5) Massachusetts, Lyman (6) Alabama, Mablis (7) Nebraska, Sharpsburg. This was a scaled-down parallel experiment of a UCLA study run earlier this year. Both the large container experiment, in which the plants were grown at UCLA, and the scaling experiment carried out at Camp Parks were prepared by blending portions of the same contaminated soil batches previously prepared at LLL.

Two sizes of plant growth containers were chosen to give 12:1 and 72:1 scale-down ratios relative to the soils used at UCLA. The following experimental parameters paralleled the UCLA study: soils used, fertiliation rates, specific soil activities (dpm/g) and plant densities (plants/cm^2 soil surface).

Comparison of the concentration ratio data from the UCB and UCLA studies will indicate how soil volumes affect plant uptake. Results from these studies could be extrapolated to give field condition values. The straw and grain obtained in this experiment will be analyzed for the radionuclides upon completion of the analyses underway as described in the previous section of this report.

Soil Contamination

The seven soils were quantitatively contaminated by dry-blending radioactive soil samples into ¼" sieved uncontaminated soil using a Patterson-Kelly liquid/solid blender at Building 332, LLL. The source of these radioactive samples was the remaining soil prepared in 1977 for the UCLA blending work at Nevada Test Site.

Preparation of Radioactive Soil Samples

The following volumes of stock solutions were combined then introduced into each soil blend. 28.27 grams of $CaCO_3$ was added to each soil blend to neutralize the spike solution carrier acid.

Spike Solution

Stock Solution	ml. of Stock Solution per Soil Blend	αdpm/Blend
$^{237}Np_x(NO_3)y$	15.15	8.88×10^8
$^{239,240}Pu(NO_3)_4$	37.47	8.88×10^{10}
$^{241}Am(NO_3)_3$	0.918*	8.88×10^9
$^{244}Cm(NO_3)_3$	3.40	8.88×10^9
TOTAL	56.94	

*Most of the ^{241}Am was contributed by the $^{239,240}Pu(NO_3)_4$ solution.

Blending weights varied between soils due to differing densities and blending characteristics. Therefore, activities per gram soil varied between soils, but total activity per nuclide in each blend was constant.

Liquid Blend Weights

Air-dry Soil

Soil	kg
Yolo	16.0
Egbert	10.0
Aiken	14.0
Holtville	18.0
Lyman	15.0
Mablis	16.0
Sharpsburg	16.0

This soil contamination procedure produced the resultant nuclide activities per gram soil.

Preparation of Liquid Spiked Soil Samples

Activity of Spiked Soil

Soil	dpm/gram			
	^{237}Np	$^{239,240}Pu$	^{241}Am	^{244}Cm
Yolo	5.55×10^4	5.55×10^6	5.55×10^5	5.55×10^5
Egbert	8.88×10^4	8.88×10^6	8.88×10^5	8.88×10^5
Aiken	6.34×10^4	6.34×10^6	6.34×10^5	6.34×10^5
Holtville	4.93×10^4	4.93×10^6	4.93×10^5	4.93×10^5
Lyman	5.92×10^4	5.92×10^6	5.92×10^5	5.92×10^5
Mablis	5.55×10^4	5.55×10^6	5.55×10^5	5.55×10^5
Sharpsburg	5.55×10^4	5.55×10^6	5.55×10^5	5.55×10^5

Dry Blending

The following components were blending together: (1) Spiked soil sample, (2) NPKS treated soil sample, (3) untreated ¼" sieved soil, and (4) in some soils $CaCO_3$ in PO_4^{-3} treated soil sample.

NPKS Treated Soil

NPKS treated soil was prepared at the Camp Parks facility. The following amounts of salts were introduced into each soil, by liquid blending:

	Grams/Blend
NH_4NO_3	33.38 gm
$(NH_4)_2SO_4$	13.61 gm
KH_2PO_4	28.03 gm

Air-dry Soil Per NPKS Blend

Soil	kg
Yolo	14.0
Egbert	10.0
Aiken	14.0
Holtville	18.0
Lyman	15.0
Mablis	16.0
Sharpsburg	14.0

Note - Soil weights per blend differ between nuclide spike blend and NPKS blend.

NPKS Treated Soil Samples

From each NPKS blend, soil samples were taken. Each sample was 1/12 of the total soil blend.

NPKS Added Per Soil Sample

	meq NO_3^-	meq PO_4^{-3}	meq K^+	meq SO_4^{-2}
NH_4NO_3	70	--	--	--
$(NH_4)_2SO_4$	17	--	--	17
KH_2PO_4	--	17	51	--
TOTAL	87	17	51	17

Note - NO_3^- in each contaminated soil sample contributed 6 meq of nitrogen. Total N added to each dry soil blend was 93 meq.

Other Soil Amendment Samples

Soil samples treated with $CaH_2PO_4 \cdot H_2O$ were prepared, for the Aiken soil blends. Final $CaH_2PO_4 \cdot H_2O$ content per sample was 153 meq PO_4^{-3}.

$CaCO_3$ treated soil samples were also prepared to raise the low pH in the Massachusetts (Lyman) and Alabama (Mablis) soils. 647 meq of $CO_3^=$ were added per soil sample for the Lyman soil and 345 meq of $CO_3^=$ per soil sample for the Mablis soil.

The procedure for the dry blending of the soil components was as follows: All of the soil samples plus untreated soil were loaded into the Patterson-Kelly Blender at Building 332, LLL. Then the soil was blended for 20 minutes with one minute of intensifier bar. Four blends were made for each soil. The following is a summary of soil sample weights blended together.

Dry Blending*

	Weight of NPKS Sample	Weight of CO_3 or PO_4 Sample	Weight of Spike Sample	Weight of Untreated Soil	Total Weight Per Blend
			kg		
Yolo	1.17	--	.167	13.45	14.79
Egbert	.840	--	.104	6.82	7.76
Aiken	1.17	.258	.146	10.22	11.80
Holtville	1.51	--	.188	14.96	16.65
Lyman	1.26	.285	.157	11.36	13.06
Mablis	1.34	.272	.167	13.26	15.04
Sharpsburg	1.17	--	.167	12.31	13.65

The first three blends per soil were weighed out and bagged for transfer to three 32-quart insulated containers. The fourth blend was weighed out and bagged in smaller amounts for transfer to four 4-quart insulated containers.

The following table is the nuclide activity in the soil after the final dry blending.

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*All weights for dry blending were determined by dividing U.C.L.A. blending weights by a factor of 12.

Activity of Potted Soil

Soil	^{237}Np	$^{239,\,240}$Pu	^{241}Am	^{244}Cm
	dpm/gram			
Yolo	6.27×10^2	6.27×10^4	6.27×10^3	6.27×10^3
Egbert	1.19×10^3	1.19×10^5	1.19×10^4	1.19×10^4
Aiken	7.85×10^2	7.85×10^4	7.85×10^3	7.85×10^3
Holtville	5.57×10^2	5.57×10^4	5.57×10^3	5.57×10^3
Lyman	7.11×10^2	7.11×10^4	7.11×10^3	7.11×10^3
Mablis	6.16×10^2	6.16×10^4	6.16×10^3	6.16×10^3
Sharpsburg	6.79×10^2	6.79×10^4	6.79×10^3	6.79×10^3

Plant Growth Container Preparation

1. 32 Quart Family Products Ice Chest

These containers are double vinyl walled with polyurethane insulation. Brass Swagelok fittings were substituted for stock plastic drainage spouts, then the containers were leak tested. 30 mesh stainless steel screen (4"x9") was placed over the fitting inside the container. A 4"x12" sheet of fiberglass cloth was taped over the screen to prevent sand from flowing into the fitting. 4 kg of Monterey #4 silica sand (∼2.5 cm) was placed evenly on the container bottom. The sand was covered with a sheet of fiberglass.

2. 4 Quart Igloo Coolers

These containers are double walled vinyl with polyurethane insulation. Brass Swagelok fittings were substituted for stock plastic drain spouts, and leak tested. 1 cm of cement was poured onto the container bottom to bring the base even with the fitting opening. After the cement dried, a layer of Amercoat was applied to seal the cement. A 6"x6" 30 mesh stainless steel screen was placed on the container bottom over the fitting.

A 8"x3" sheet of fiberglass cloth was taped over the fitting to prevent sand from flowing under the screen. Then 1 kg (~2.5 cm) of Monterey #4 silica sand was placed evenly over the bottom, followed by a 8"x8" sheet of fiberglass.

Potting

The blended contaminated soil was potted by transferring pre-weighed, bagged soil to individual plant growth containers. The transfers were performed on the downdraft table at Building 332, LLL. The containers were double bagged to prevent external contamination. One bag was removed as the soil transfer was completed, and the container was taken off the downdraft table.

The following table summarizes soil weights transferred to each container and the number of replicates per soil.

	Soil Weight in 32 Quart Containers		Soil Weight in 4 Quart Containers	
Soil	kg	Reps.	kg	Reps
Yolo	14.79	3	2.47	4
Egbert	7.76	3	1.29	4
Aiken	11.80	3	1.97	4
Holtville	16.65	3	2.78	4
Lyman	13.06	3	2.18	4
Mablis	15.04	3	2.51	4
Sharpsburg	13.65	3	2.28	4

Planting

Prior to planting in a hood, all soils were brought up to 50% water holding capacity and the interior side walls were cleaned, swiped and α counted.

INIA 66R wheat seed was aerated in distilled water for 24 hours before planting. A plant density of one seed per 25 cm^2 of soil surface was constant for both container sizes. 40 seeds were planted in the 32 quart containers, and 10 seeds were planted in the 4 quart containers; 0.5kg/small container and 2 kg/large container of Monterey #4 silica sand was placed evenly over the seeds and soil. The second bag was removed from the containers, when the planting procedure was complete. The containers were sealed and shipped to the Camp Parks facility.

Plant Growth Period

The plant growth containers were placed in the Plutonium Greenhouse at Camp Parks. The lids of all containers were kept on for four days. When most plants were up and the lids were removed, 1.2 cm of Monterey #4 silica sand was added and leachate collection systems were connected.

The external and internal container surfaces were swiped and α counted. During the plant growth period, swipe discs were placed on the sand surfaces and counted periodically to detect any contaminated soil coming to the surface.

Uncontaminated control containers were prepared and utilized to monitor soil moisture and soil temperature; ∿5% leach was obtained from all containers and collected in 4 liter polyethylene bottles.

The plants were grown to maturity and allowed to naturally dry out. The leachate collection apparatus was disconnected and the leachate samples were sealed and stored for future analysis. The plants were then photographed.

Harvest

The average plant height per container was determined and the plants were separated into three components: (1) Heads, (2) Upper stem vegetation, and (3) Lower stem vegetation.

Each container was harvested by first severing the heads at their bases, and bagging them. The upper half of the remaining vegetation above the container lip was severed and bagged as upper stem vegetation. The vegetation remaining was cut at the level of the container lip and bagged as lower stem vegetation.

Observations

4-17-78	Wheat seeds planted in large containers (LLL).
4-18-78	Large containers shipped to Camp Parks.
4-21-78	Lids removed from large containers.
4-25-78	Large container plants in 2 leaf stage.
4-26-78	Wheat planted in small containers (LLL).
4-27-78	Small containers shipped to Camp Parks.
4-30-78	Lids removed from small containers.
5-3-78	Small container plants in 2 leaf stage.
5-30-78	Large container wheat heading out.
6-5-78	Small container wheat heading out.
	Large container wheat in pollen stage.
6-12-78	Large container wheat in milk stage.
	Small container wheat in pollen stage.
6-19-78	Large container wheat in soft dough stage.
	Small container wheat in milk stage.
7-5-78	Large container wheat in hard dough stage.
	Small container wheat in soft dough stage.
7-12-78	Small container wheat in hard dough stage.
7-28-78 to 8-1-78	Harvest

	Planting to Harvest	Days
Large Container	4-17-78 to 7-28-78	102
Small Container	4-26-78 to 7-28-78	93

Harvest Yields
Air-dry Weights

32 Quart Container		Heads	Upper Stem Vegetation	Lower Stem Vegetation
		grams		
Yolo -	1	57.65	13.94	26.80
	2	36.42	13.22	20.94
	3	40.43	19.59	19.26
Egbert -	1	99.14	17.28	33.35
	2	96.27	21.44	31.36
	3	93.34	17.33	30.54
Aiken -	1	61.40	14.48	27.32
	2	50.85	18.21	30.72
	3	47.74	14.10	27.21
Holtville -	1	56.89	14.75	25.08
	2	75.66	14.35	27.62
	3	68.50	13.86	25.63
Lyman -	1	21.90	6.22	9.13
	2	32.05	8.15	11.22
	3	18.79	5.58	8.05
Mablis -	1	54.44	13.28	24.05
	2	40.49	13.20	23.70
	3	66.33	14.42	26.73

Harvest Yields
Air-dry Weights (continued)

32 Quart Container		Heads	Upper Stem Vegetation	Lower Stem Vegetation
		grams		
Sharpsburg -	1	73.06	13.93	24.97
	2	56.29	14.61	24.47
	3	61.42	16.88	24.27

Harvest Yields

Air-dry Weights

4 Quart Container		Heads	Upper Stem Vegetation	Lower Stem Vegetation
		grams		
Yolo -	1	14.85	2.04	3.75
	2	10.57	1.86	4.03
	3	13.05	2.47	3.81
	4	11.91	2.20	3.46
Egbert -	1	16.20	3.56	3.92
	2	14.66	2.25	4.63
	3	15.30	2.33	4.56
	4	13.81	2.50	4.40
Aiken -	1	12.86	1.85	4.04
	2	14.01	2.03	5.21
	3	13.03	2.23	4.43
	4	14.72	2.13	4.58
Holtville -	1	11.29	1.59	3.78
	2	12.12	2.01	4.21
	3	11.50	2.14	3.74
	4	13.75	2.09	4.39

Harvest Yields

Air-dry Weights (continued)

4 Quart Container		Heads	Upper Stem Vegetation	Lower Stem Vegetation
		grams		
Lyman -	1	4.46	1.66	3.85
	2	9.77	2.25	4.67
	3	8.06	2.02	3.88
	4	8.88	2.52	4.30
Mablis -	1	11.85	2.45	3.32
	2	13.06	2.14	4.38
	3	11.35	1.87	3.99
	4	12.69	2.10	4.72
Sharpsburg -	1	12.38	2.09	3.48
	2	13.29	2.08	3.66
	3	11.97	1.93	3.38
	4	14.31	2.20	4.21

PLANT UPTAKE OF TRANSURANIC ELEMENTS FROM SOIL: VERIFICATION OF ANALYTICAL AND EXPERIMENTAL PROCEDURES

This study has two purposes as its goal. One purpose was confirmation of radiochemical analytical procedures. To this end, a wheat crop grown on 13 containers was composited and mixed to give a large sample for analyses. Twelve sub-samples have been taken from this large mixed sample and are being analyzed at Berkeley using the radio-chemical procedure described in the preceeding section of this report. Also, sub-samples from this large batch are being sent to UCLA and LASL for analyses. The data obtained at the three laboratories is then to be compared. The other purpose of this study is to investigate the inherent pot-to-pot variability of plant uptake of transuranics in this type of experiment. To this end, the straw and grain from a wheat crop grown on a an additional 12 containers is being analyzed individually. In all, 25 containers were used in this experiment. This study should form a firm basis for the other experiments to follow in this project.

^{237}Np, ^{238}Pu, ^{239,240}Pu, ^{241}Am, and ^{244}Cm were added to Yolo soil used in this experiment. Yolo soil was selected as this soil is a fertile agricultural soil and is representative of a large acreage in California. INIA 66R wheat was chosen as the test plant and four-quart insulated coolers were selected for plant growth containers. Experimental parameters were constant for all containers.

Soil Contamination

The contaminated soil was prepared using a Patterson-Kelly liquid/solid blender at Building 332, LLL. 14.0 kg of Yolo soil was contaminated by blending in a radioactive spike solution. Samples of the contaminated soil were then blended with NPKS treated soil samples and untreated soil.

1. Liquid Blending

The spike solution was prepared by combining the following aliquots from stock solutions.

Spike Solution

Stock Solution	ml. From Stock Solution	dpm/Nuclide
$^{237}Np_x(NO_3)_y$	6.69	3.92×10^8
$^{238}Pu(NO_3)_4$	19.70	3.92×10^{10}
$^{239,240}Pu(NO_3)_4$	16.54	3.92×10^{10}
$^{241}Am(NO_3)_3$	.185*	3.92×10^9
$^{244}Cm(NO_3)_3$	1.50	3.92×10^9
TOTAL	44.62 ml	

22.47 grams of $CaCO_3$ were required to neutralize the spike solution carrier and acid.

The blender was charged with 14.00 kg of <2-mm sieved Yolo soil and the 22.47 grams of $CaCO_3$ was sprinkled over the soil. The $CaCO_3$ was blended into the soil for 20 minutes. The 44.62 ml spike solution was quantitatively transferred to the delivery vessel and diluted up to 300 ml with 0.1N HNO_3. The spike solution was then introduced into the soil over 12 minutes, followed by two 50 ml 0.1N HNO_3 rinses. Total spike time - 30 minutes. The soil was loaded into the blender and reblended for a total of 60 minutes. To verify the uniformity of the blend .5-gram soil samples were taken, gamma counted (59.6 keV) and compared.

The following are the soil activities after the liquid blending:

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*Most of the ^{241}Am was contributed by the $^{239,240}Pu(NO_3)_4$ solution.

Soil Activity

Isotope	α dpm/gram Soil
^{237}Np	2.80×10^4
^{238}Pu	2.80×10^6
$^{239,240}Pu$	2.80×10^6
^{240}Am	2.80×10^5
^{244}Cm	2.80×10^5

2. Dry Blending

The dry blending was preformed by mixing the following components: (1) 2.00 kg of contaminated soil, (2) 1.17 kg of NPKS treated soil, and (3) 10.83 kg of untreated ¼" sieved Yolo soil.

Due to the increased soil activity levels in this experiment relative to the seven soil scale-down experiment, additional NO_3 was introduced into the soil from the spike solution. To maintain approximately equivalent fertilization levels, all of the NH_4NO_3 was omitted when the NPKS soil samples were prepared.

Fertilizer in Milliequivalents per 1.17 kg Sample

	meq NH_4^+	meq PO_4^{-3}	meq K	meq SO_4^{-2}
$(NH_4)_2SO_4$	17	--	--	17
KH_2PO_4	--	51	17	--

The 2.00 kg contaminated soil sample introduced 64 meq NO_3^- to the dry blend. The total NPKS added to each 14.0 kg blend was:

NO_3^- - 81 milliequivalents

PO_4^{-3}- 51 milliequivalents

K^+ - 17 milliequivalents

SO_4^{-2}- 17 Milliequivalents

Each soil batch was blended for 20 minutes, with 1 minute of intensifier bar to break up any soil aggregates. A total of five dry blends were prepared. The blended soil was bagged, and weighed for transfer to the four-quart containers. The following table gives the resultant soil activity after dry blending.

Soil Activity

Isotope	α dpm/gram Soil
^{237}Np	4.00×10^3
^{238}Pu	4.00×10^5
$^{239,240}Pu$	4.00×10^5
^{241}Am	4.00×10^4
^{244}Cm	4.00×10^4

Plant Growth Containers

Four-quart Igloo insulated coolers were utilized and modified using the procedure described in the next section of this report.

Potting

2.50 kg of the dry-blended contaminated soil was transferred to each container. A total of 25 containers were prepared on the down-draft table in Building 332, LLL. The containers were double-bagged to prevent exterior contamination. One bag was removed after the soil transfer was completed.

Planting

Prior to planting, in a hood, interior wall surfaces of the containers were cleaned, swiped, and counted. Then the Yolo soil was brought up to 50% WHC. INIA66R wheat was aerated 24 hours prior to planting, and 10 seeds were placed in each container. 500 grams of Monterey #4 silica sand was spread over the seeds and soil. The second bag was removed from the containers when the planting procedure was completed. The containers were sealed and shipped to the Camp Parks Facility.

Plant Growth Period

The containers were placed in the plutonium greenhouse at Camp Parks. Contamination monitoring, experimental observations and leach collection systems were identical to those in the prior experiment. The plants were grown to maturity and ∿5% leach was collected during the growth period. Leachate collection systems were disconnected and the plants were photographed.

Harvesting consisted of observations followed by separating the plants into three components: (1) heads, (2) upper stem vegetation, (3) lower stem vegetation. The same procedure was used as described in the next section of this report.

OBSERVATIONS

6-21-78	Wheat planted at LLL
6-22-78	Containers shipped to Camp Parks
6-26-78	Lids removed from containers
6-28-78	Wheat plants in 2-leaf stage
7-21-78	Plants head out
7-31-78	Pollen stage
8-14-78	Milk stage
8-21-78	Soft dough stage
8-30-78	Hard dough stage
9-25-78	Harvest

Planting to harvest 6-21-78 to 9-25-78 -- 96 days

Harvest Yields

Air-dry Weights

Container	Heads	Upper Stem Vegetation	Lower Stem Vegetation
	grams		
Yolo - 1	16.07	3.61	5.79
2	15.36	3.67	5.30
3	16.11	2.81	4.83
4	16.20	2.81	4.32
5	14.54	3.68	5.39
6	17.09	2.60	5.14
7	16.01	2.70	4.87
8	13.06	2.58	4.51
9	15.68	3.13	5.39
10	13.81	2.02	4.93
11	14.73	2.64	5.04
12	14.31	2.38	4.82
13	13.73	2.54	4.25
14	14.76	3.85	5.79
15	14.24	3.23	4.20
16	13.69	2.38	4.63
17	11.90	2.43	4.08
18	15.03	3.03	4.27
19	13.61	2.96	4.54
20	13.54	2.69	3.97
21	11.98	2.55	4.15
22	14.33	2.52	4.46
-23	13.26	2.58	4.16
24	11.81	2.43	3.87
25	10.35	2.97	4.00

SOIL CONCENTRATION EFFECTS ON PLANT UPTAKE OF TRANSURANIC ELEMENTS

This experiment was designed to investigate how transuranic nuclide soil concentrations effect plant uptake. INIA 66R wheat was grown on Yolo soil, a fertile California agricultural soil. The soil was contaminated with ^{237}Np, ^{238}Pu, ^{239,240}Pu, ^{241}Am and ^{244}Cm at six activity levels. The isotope ratios at each contamination level were constant and equal to those of the prior two experiments.

One objective of this study was to show the relative uptake between ^{238}Pu and ^{239,240}Pu. The higher specific activity (dpm/g) of ^{238}Pu causes greater crystal damage and radiolysis than that of ^{239,240}Pu. This difference may cause ^{238}Pu to have a higher water solubility, which enhances its availability and uptake by plants.

The plutonium soil concentration range was selected to give an overlap of atoms ^{238}Pu/gram soil and atoms ^{239,240}Pu/gram soil. The overlap allows for two types of uptake comparisons to be made. One comparison can be made on the basis of equal Pu nuclide dpm/gram soil levels and the other on the basis of equal Pu nuclide atoms/gram soil levels. Additional atoms/gram soil overlaps exist between the following nuclide pairs: ^{238}Pu - ^{241}Am, ^{241}Am - ^{244}Cm, and ^{237}Np - ^{239,240}Pu.

Modified four quart insulated coolers were chosen for plant growth containers. Soil volumes, fertilization rates, isotopes and plant densities were constant for all soil contamination levels.

Soil Contamination

Quantitative soil contamination was accomplished by doing six liquid/soil blends in a Patterson-Kelly liquid/solid blender at Building 332, LLL. Each soil blend was contaminated with a separate spike solution, and includes a nutrient treated soil sample. A primary solution was prepared for the highest level contamination. Successive dilutions were made up, for the other five spike solutions.

Due to the fixed dpm/HNO_3 ratio in the stock solutions, the highest contamination levels would have introduced excessive NO_3^- to the soil. Therefore, the two largest contributors of NO_3^- to the spike solution ($^{238}Pu(NO_3)_4$ and $^{239,240}Pu(NO_3)_4$) were concentrated to increase the dpm/HNO_3 ratio. The following are the stock solution aliquots pulled to make the primary solution.

Stock Solution	ml From Stock Solution	dpm/nuclide
$^{237}Np_x(NO_3)_y$	15.10	8.85 x 10^8
$^{238}Pu(NO_3)_4$	44.47	8.85 x 10^{10}
$^{239,240}Pu(NO_3)_4$	37.34	8.85 x 10^{10}
$^{241}Am(NO_3)_3$	--*	8.85 x 10^9
$^{244}Cm(NO_3)_3$	3.39	8.85 x 10^9
TOTAL	100.3	

*All ^{241}Am was contributed by $^{239,240}Pu(NO_3)_4$ solution.

Before the $^{238}Pu(NO_3)_4$ and $^{239,240}Pu(NO_3)_4$ were combined with other aliquots, these two aliquots were transferred to a 150 ml beaker and simmered down to ∿5 ml on a hot plate. 25 ml of .1N HNO_3 was added and the solution was allowed to cool. 1 ml of 30% H_2O_2 was added to the solution and simmered to release residual H_2O_2. 1 ml of 30% H_2O_2 was added again and the solution was simmered until bubbling ceased. The solution was allowed to cool and transferred quantitatively to a 100 ml volumetric flask, using 0.1N HNO_3. The aliquots of $^{237}Np_x(NO_3)_y$ and $^{244}Cm(NO_3)_3$ were transferred to the 100 ml volumetric flask and the solution was brought up to volume with 0.1N HNO_3.

An aliquot of this solution was titrated against a known NaOH standard and the $[H^+]$ was determined to be 2.38 N. The diluent for the following five dilutions was 2.38 N HNO_3.

The second dilution was prepared by transferring 31.62 ml of the first dilution to a 100 ml volumetric flask and diluting to 100 ml with 2.38 N HNO_3. Dilutions #3 through #6 were prepared using the same procedure, diluting 31.62 ml of the prior dilution to 100 ml with 2.38 N HNO_3. The following is the dpm per ml per nuclide for the six dilutions.

Spike Solution Activity

Dilution #	^{237}Np	^{238}Pu	$^{239,240}Pu$	^{241}Am	^{244}Cm
	dpm/ml				
1	8.85×10^6	8.85×10^8	8.85×10^8	8.85×10^7	8.85×10^7
2	2.80×10^6	2.80×10^8	2.80×10^8	2.80×10^7	2.80×10^7
3	8.85×10^5	8.85×10^7	8.85×10^7	8.85×10^6	8.85×10^6
4	2.80×10^5	2.80×10^7	2.80×10^7	2.80×10^6	2.80×10^6
5	8.85×10^4	8.85×10^6	8.85×10^6	8.85×10^5	8.85×10^5
6	2.80×10^4	2.80×10^6	2.80×10^6	2.80×10^5	2.80×10^5

A 50 ml aliquot from each dilution was introduced into the respective blend. A total of 250 ml of 0.1N HNO_3 was used as a diluent and rinse during the spike. 7.206 grams of $CaCO_3$ were added to the soil prior to spiking to neutralize the spike solution acid because the HNO_3 content per spike solution was constant and contributed a large amount of NO_3^- to the soil, the NPKS sample preparation was modified. All NH_4NO_3 and $(NH_4)_2SO_4$ was omitted. The NO_3^- was provided in total by the spike solution.

NPKS Soil Sample

	meq NO_3^-	meq PO_4^{-3}	meq K	meq SO_4^{-2}
KH_2PO_4	0	51	17	0

The nuclide spike solution introduced 144 meq of nitrogen to the soil.

	Total NPKS Added per 14 kg Blend
NO_3^-	144 meq
PO_4^{-3}	51 meq
K^+	17 meq
SO_4^{-2}	0

Blending Procedure

The P-K blender was charged with 1.12 Kg of PK treated soil plus 12.88 kg of untreated Yolo soil. 7.206 grams of $CaCO_3$ were blended into the 14.00 kg of total air dry soil for 20 minutes. The 50 ml spike (dilution) was quantitatively transferred to the delivery vessel, diluted to 200 ml with 0.1N HNO_3 and introduced into the soil over ∿15 minutes. This was followed with 2-50 ml 0.1N HNO_3 rinses. Total spike time was 30 minutes.

The contaminated soil was transferred into the loading bin and allowed to air dry overnight. The soil was reloaded into the blender and dry blended for one hour.

In order to verify the uniformity of the blend, 0.5 gram soil samples were taken, gamma counted (59.6 kev) and compared. The maximum tolerable variance from mean was 10%. The soil was then weighed out and bagged.

The following are the resultant soil activities after contamination blending.

		Soil Activities				
		^{237}Np	^{238}Pu	^{239,240}Pu	^{241}Am	^{244}Cm
Activity Level	Number of 14 kg Blends	dpm/gram Soil				
1	2	1.00×10^2	1.00×10^4	1.00×10^4	1.00×10^3	1.00×10^3
2	1	3.16×10^2	3.16×10^4	3.16×10^4	3.16×10^3	3.16×10^3
3	1	1.00×10^3	1.00×10^5	1.00×10^5	1.00×10^4	1.00×10^4
4	1	3.16×10^3	3.16×10^5	3.16×10^5	3.16×10^4	3.16×10^4
5	1	1.00×10^4	1.00×10^6	1.00×10^6	1.00×10^5	1.00×10^5
6	1	3.16×10^4	3.16×10^6	3.16×10^6	3.16×10^5	3.16×10^5

The blending was performed by starting with the lowest contamination level and finishing with the highest.

Plant Growth Containers

Four-quart insulated Igloo coolers were utilized and fitted identically to those in the prior two experiments.

Potting

Five 2.50-kg replicates were potted per blend into the Igloo containers, except for the lowest contamination level in which ten 2.50-kg replicates were potted. A total of 35 containers were filled on downdraft table at Building 332, LLL. Container bagging was the same as before.

Planting

The de-contamination and planting procedures were also the same as before.

Plant Growth Period

At Camp Parks, the containers were placed in the Greenhouse, and again the same procedures as before were carried out. One exception was the use of cheesecloth to decrease light intensity to plants.

This experiment is still currently in the plant growth stage. It too will be grown to maturity, harvested and radio-chemically analyzed. Harvest of this experiment will be in December, 1978.

Experiment Observations

9-11-78	Wheat planted at LLL.
9-12-78	Containers transported to Camp Parks.
9-15-78	Lid removed from Igloos.
9-18-78	Second leaf stage.
10-23-78	Wheat heads out.
11-2-78	Pollen stage.
11-78	Still in progress.

Stable Elements on Uptake of Counterpart Radionuclides Under Waste Management Conditions

It is well-known that stable elements act as carriers for respective radionuclides and that carrier and dilution effects can occur. What is not well-known or appreciated is that natural levels of some of the stable elements in soil or even high levels of the same elements added as waste chemicals to storage trenches can have profound effects on the mobility and plant uptake of the respective radionuclides.

As mentioned in the next two sections of this report, a tremendous amount of effort was made by the radioecologists of the world in relating plant availability of ^{90}Sr to its ratio to calcium and that of ^{137}Cs to its ratio of potassium. In each case the element pairs represented analogs or congeners. It is assumed that the chemical behavior is so similar in each case that one could almost trace the other.

More recent studies have indicated that calcium and strontium behave almost like opposites in distribution and redistribution in plants. Cesium and potassium have a somewhat similar behavior but not as intense.

The objective of the next two papers in this report is to show that stable strontium and stable cesium have profound effects on uptake of their respective radionuclides. We have observed that stable strontium is an abundant element in natural ecosystems around the USA and consequently there is plenty of it in plants and soils. It, rather than calcium, can be the principal carrier of ^{90}Sr in food chains. Stable strontium levels must be one parameter going into useful models of ^{90}Sr cycling.

Less is known about stable cesium in natural ecosystems than of stable strontium. It is recognized, however, that cesium is ubiquitous in natural systems and that plants contain at least a few nanograms per gram of dry weight.

In addition to the natural levels of these two elements, the waste levels of them must also be ascertained and considered.

EFFECT OF STABLE Sr SUPERIMPOSED UPON SOIL UNIFORMLY CONTAMINATED WITH ^{85}Sr ON UPTAKE OF ^{85}Sr BY BUSH BEAN PLANTS

Abstract: Bush bean plants were grown for 14 days in Yolo loam soil to which ^{85}Sr had been blended uniformly. Stable Sr was also applied at rates of 0, 10, 25, and 100 μg/g soil. The results in uptake of ^{85}Sr and stable Sr implied that there were somewhere between 10 and 15 μg native available Sr per g soil. The applied radiostrontium equilibrated with this so that there was no effect of added Sr on absolute uptake of ^{85}Sr. It was then postulated that native soil Sr would have much greater effect on radio Sr transport than would soil Ca. The Y value for Sr uptake was near ln 2.

Introduction

In a preceding report, the role of stable Cs on uptake and movement of ^{137}Cs in plants was considered. It was observed that stable Cs had much influence on the uptake and transport of ^{137}Cs in plants. Soils and plants are supplied with a relatively abundant supply of native Sr, and the purpose of this study was to explore effects of stable Sr on uptake and transport of ^{85}Sr which could be an indication of the behavior of ^{90}Sr.

Considerable effort has been expended on Ca-Sr interrelations in plant uptake (Comar et al. 1957; Nishita et al. 1978; Romney et al. 1969; Menzel et al. 1959; Resnik et al. 1969) just as for Cs-K interrelations. It could be expected that Sr-^{90}Sr relationships could be more important than ^{90}Sr-Ca relationships even though the latter have been studied much more than the former.

Nishita et al (1978) suggest that stable Sr and radio Sr behave essentially the same in plant soil relationships so some review of stable Sr effects at this time is of interest. Both Ca and Sr appear to move passively into roots but must pass a metabolic barrier before being transferred to shoots from roots (Wallace et al, 1971).

In analysis of native plant species from the desert, there is a high degree of correlation between Ca and Sr concentrations in plants (Romney et al, 1973, 1976; Wallace and Romney 1971, 1972; Wallace, 1971). This in part could reflect the simultaneous abundance of both Ca and Sr in desert soils. When Ca and Sr were both varied in solution culture studies, Sr tended to accumulate more in roots and in stems while Ca accumulated more in leaves (Wallace and Romney, 1971a). This indicates that lime and other Ca additions can suppress Sr accumulation in plant parts (Wallace, 1971bc). Ca and Sr differentially re translocate from old plant parts to new plant parts (Wallace et al, 1971; Wallace et al, in preparation). These results emphasize that careful attention must be given to behavior of stable Sr if behavior of ^{90}Sr is to be understood in the soil-plant system.

Materials and Methods

Stable Sr as $Sr(NO_3)_2$ was uniformly blended with Yolo loam soil (fine-silty, mixed, thermic Typic Xerorthents) at levels of 0, 10, 25 and 100 µg Sr per g of soil. ^{85}Sr, essentially carrier free, was blended separately with all soil at the level of 38800 dpm per g soil. Bush bean seedlings (Phaseolus vulgaris L. CV Improved Tendergreen) were transplanted to 500 g quantities of the soil with 4 replications and grown for 2 weeks. Nitrogen was applied to the soil at a rate of 200 µg N/g soil as NH_4NO_3 or $SR(NO_3)_2$ and soil moisture was maintained near -1/3 bar.

Plant shoots were separated to primary leaves, trifoliate leaves and stems, then counted for ^{85}Sr by gamma scintillation well counting. A similar set of plants not exposed to ^{85}Sr was assayed for mineral elements by emission spectrography.

Results and Discussion

There was little difference in the amounts of ^{85}Sr in these plant parts at the different added levels of stable Sr (Table 1). This meant only that the specific activity decreased with added stable Sr. At the highest level of applied stable Sr the specific activity in plant parts was essentially the same as that applied if they had been uniformly mixed. This implies that the 100 µg Sr/g soil completely swamped the level of native Sr in soil. In leaves and stems with the treatment, the relative stable Sr concentrations relative to zero application were about 6:1 but with little difference in dpm per g dry weight. This then would imply a concentration of available native soil Sr of about 16 µg/g. When the applied level of stable Sr was 25 µg/g the ratios were about 3:1 which would imply that the native soil Sr would be about 13 µg/g*. With 10 µg Sr per g soil the ratios are near 2:1 implying about 10 µg Sr per g soil. These values (16, 13, 10) are within reasonable range of each other and indicate that for this particular soil any radioactive Sr would be quickly equilibrated with the stable Sr in soil and that supply of native soil would dictate the mobility of the radio Sr.

If the native available soil Sr were 10 µg/g then the 4 levels used in this study were 10, 20, 35, and 110 rather than 0, 10, 25 and 100 µg/g. Calculated Y values from the equation $\left(\frac{C_1}{C_2}\right)^Y$ = uptake ratio (Wallace, 1977)

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* $\frac{25 + X}{X} = 3;\ X = 13$

would average about 0.7 or near ln 2 with these corrected values for stable Sr.

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Table 1. Stable Sr and ^{85}Sr in bush bean plants grown in Yolo loam soil for 14 days with different levels of added stable Sr.

Applied Stable Sr µg/g Soil	Sr in plants µg/g	Ca in plants %	Ca/Sr ratio	^{85}Sr in plants dpm/g	S.A. in plants dpm/µg Sr	S.A. applied dpm/µg Sr	Actual S.A./ theoretical S.A. %
Primary leaves							
0	72	3.33	463	183,600	2550	-	-
10	144	3.73	259	172,300	1196	3880	31
25	245	4.27	174	254,600	1039	1552	67
100	399	3.98	100	217,600	545	388	140
Trifoliate leaves							
0	30	0.78	250	62,700	2090	-	-
10	81	2.01	248	109,600	1353	3880	35
25	100	1.53	153	86,100	861	1552	55
100	193	1.28	66	74,200	384	388	99
Stems							
0	64	1.50	234	142,500	2227	-	-
10	114	1.91	168	142,000	1246	3880	32
25	159	1.87	118	146,500	921	1552	59
100	323	1.83	57	125,600	389	388	100
F value	45.3**	22.7**	-	20.7**	-	-	-
LSD 0.05	46	0.68	-	17,860	-	-	-
LSD 0.01	61	0.90	-	23,580	-	-	-

S.A. is specific activity.

THE ROLE OF STABLE Cs ON PLANT UPTAKE OF ^{137}Cs

Abstract: A series of studies is being conducted to more fully evaluate the role of stable Cs on plant uptake of ^{137}Cs. Stable Cs applied to soil simultaneously with ^{137}Cs greatly increased uptake of ^{137}Cs by bush bean plants. Stable Cs applied just after ^{137}Cs was only half as effective in increasing uptake as Cs applied with the ^{137}Cs because the two were not fully equilibrated. Most ^{137}Cs was accumulated in primary leaves in contrast to trifoliate leaves and stems of the plants. When bush beans were grown in pots of varying size, plants of small pots contained much more Mn, less K in primary leaves, and less ^{137}Cs in all plant parts than large plants. Most Mn was in primary leaves. Three consecutive barley cuttings from the same pots resulted in less ^{137}Cs in plants from small pots per unit of dry weight than from large pots and in less K, more Ca and more ^{137}Cs in the third crop. The first crop besides being lowest in ^{137}Cs was also lowest in Ca, Mg, P, Mn, Cu, Zn and Sr relative to the second and third crops.

Introduction

The processes in which some radionuclides are becoming "aged" in their equilibration with soil have been going on for decades. One possibility for change in radionuclide availability with time may be the degree to which at least some radionuclides become equilibrated with their stable counterparts in soil. Such possibility exists for the ^{137}Cs radionuclide in that soil always contains some stable Cs. Soil concentrations for a desert soil was 4 μg Cs/g soil with a K:Cs ratio of about 5000 (Wallace et al. 1971). It is well-known that small applications of stable Cs to soil can greatly increase plant uptake of stable Cs which is supposedly a carrier effect (Nishita et al. 1962). Large applications of stable Cs can decrease uptake of Cs by isotope dilution.

Another aging mechanism is that ^{137}Cs does seem to become fixed on or in the clay lattice with time and hence becomes less available for that reason (Nishita et al. 1960, 1965).

The purpose of this series of studies is not to redo past researches but to explore the possibility of the need for a study of cycling of stable Cs through ecosystems as well as for studies of movement of ^{137}Cs through the ecosystems. A preliminary study of stable Cs in an ecosystem at the Nevada Test Site was made (Wallace et al. 1971). The present study is partly completed only at this time.

Materials and Methods

Experiment 1. Stable Cs applied to soil with ^{137}Cs simultaneously and similar applications applied separately.

Radioactive Cs (^{137}Cs) was equilibrated with quantities of Yolo Loam soil (fine-silty, mixed, thermic Typic Xerorthents) at the rate of 30,800 dpm/g soil. Part of the soil received ^{137}Cs carrier free; the remainder received an equivalent amount of ^{137}Cs but with 100 or 200 μg Cs/g soil so that the stable Cs and ^{137}Cs would not be equilibrated at least initially. The Cs applications were made to soil spread out thinly and then homogenized for one hour in a V blender for each separate combination. The soil receiving ^{137}Cs and Cs separately had two separate blendings.

Bush bean (Phaseolus vulgaris L. CV Improved Tendergreen) seedlings were planted into pots of 1000 g soil with 4 replicates per treatment.

Nitrogen was applied at the rate of 200 µg N/g soil as NH_4NO_3. Soil moisture was maintained near -1/3 bar. After 16 days plants were separated to primary leaves, trifoliate leaves and stems, and counted for ^{137}Cs with gamma scintillation counting. Eventually a similar set of plants grown without ^{137}Cs will be assayed for stable Cs.

Experiment 2. Bush beans and barley grown with carrier free ^{137}Cs in soil in pots of varying size.

Pot size was varied at 2000, 1000, 500 and 250 g soil. Bush bean plants as above were grown in Yolo loam soil as above for 14, 19, and 27 days respectively for 2000, 1000, and 500 and 250 g pots respectively. The activity in soil was 11,180 dpm $^{137}Cs/g$. Nitrogen was applied as above and soil moisture was also maintained as above. Plants were handled as above.

After the bush beans were grown, more nitrogen was added and barley (Hardeum vulgare L. Atlas 57), 20 plants were grown per pot for 22 days. Shoots were cut 2 cm above the soil line and a second crop was removed at 36 days and a third at 50 days. Each was counted and a non-radioactive set of three were assayed for mineral nutrients by emission spectrography.

Results and Discussion

Experiment 1.

Both rates of stable Cs increased accumulation of ^{137}Cs in all plant parts analyzed (Table 1). When ^{137}Cs was mixed with stable Cs before being applied to soil the accumulation of ^{137}Cs in trifoliate leaves and stems was double that of plants grown in soil in which they were applied separately. This demonstrates the validity of the carrier effect on increased ^{137}Cs uptake (Fig. 1). It also demonstrates the impossibility of uniform mixing of radionuclides with soil. Actually the degree of mixing of stable Cs with ^{137}Cs indicated by the 100 and 200 μg Cs/g soil when they were applied separately from ^{137}Cs was remarkably good. The carriers increased ^{137}Cs uptake by 8 and 10 times respectively even though the uptake with each was doubled that when they were mixed before application to assure the carrier effect.

The levels of stable Cs applied to this soil were relatively high (0.08 and 0.16 me/100 g soil). These levels are much higher than can be expected for exchangeable Cs under natural conditions. This implies a carrier effect which would increase uptake for any and all lower levels which may be applied or for levels found in natural ecosystems.

Experiment 2.

Bush bean plant growth was decreased with small pot sizes (Table 2). The manganese levels were increased in plant parts especially in the primary leaves with decrease in pot size. Primary leaves accumulated the greatest amount of ^{241}Am when DTPA chelate was supplied (this report) and also of several different trace metals when applied in excess. It is not known if excess manganese contributed to the yield depression of the plants in small pots.

One reason for this type of experiment was that it was expected that the small pot size would induce a K deficiency especially with continued cropping and that native Cs in the soil would likewise become depleted. The primary leaves of bush bean did indicate some K stress (K translocated from primary leaves to new growth).

Simultaneously there were decreases in ^{137}Cs in plants as plants decreased in size. Stable Cs analyses have not yet been completed.

Three successive crops of barley shoots resulted in a slight depression in K for the smallest pots in the second and third cuttings (Table 3). None of the nutrient metals followed this pattern. The concentration of ^{137}Cs in the shoots simultaneously was greatly increased. Further evaluation of this phenomenon must await completion of stable Cs analysis. In the first barley cutting, ^{137}Cs, Mg, P, Mn, Cu, Zn, and Sr were lowest of the three cuttings.

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Table 1. ^{137}Cs in bush beans grown in a glasshouse in soil in which had been blended ^{137}Cs and stable Cs added either separately or together.

	Mean ^{137}Cs accumulation			Coefficient of variation		
Stable Cs	Primary leaves	Trifoliate Leaves	Stem	Primary leaves	Trifoliate Leaves	Stem
μg/g soil		dpm/g			%	
Control	1260	1280	796	17	53	30
100 separately	11500	11500	8200	32	27	19
100 together	19200	18100	10900	40	17	28
200 separately	15500	17300	10950	13	9	13
200 together	50100	42300	30500	18	15	27
F value	43.5	69.3	29.5	-	-	-
LSD 0.05	7880	5140	5730	-	-	-

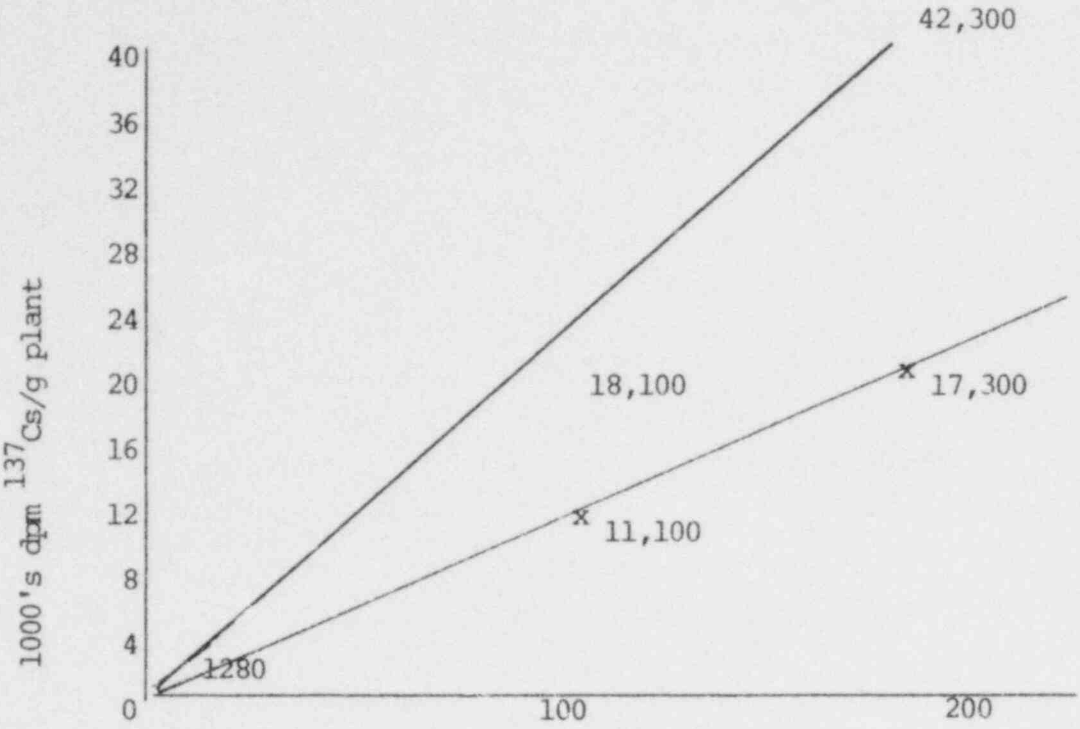
Table 2. Yields, ^{137}Cs, and mineral element in plant parts of bush beans grown in Yolo loam soil in different pot sizes.

Container Size g soil	Dry Wt* mg/p	K %	Ca %	Mg %	P %	Mn µg/g	Fe µg/g	Cu µg/g	Zn µg/g	Sr µg/g	Dry Wt** mg/p	^{137}Cs dpm/g
Primary leaves												
2000	267	1.09	6.83	0.84	0.264	276	199	11.7	18.8	156	294	1739
1000	283	1.16	7.36	0.96	0.261	515	199	10.0	24.3	185	329	1266
500	355	0.29	8.68	1.17	0.338	1035	159	10.1	24.0	220	317	769
250	306	0.29	8.53	1.27	0.219	1973	160	8.6	22.1	217	294	760
Trifoliate leaves												
2000	248	3.21	2.46	0.44	0.536	114	143	11.1	25.7	61	506	1776
1000	354	2.32	2.97	0.52	0.440	166	126	8.1	21.1	72	529	1325
500	150	1.82	4.29	0.87	0.584	359	151	12.1	26.2	100	262	1355
250	101	1.80	3.23	0.63	0.526	351	119	10.4	25.9	77	148	1405
Stems												
2000	83	2.14	2.92	0.50	0.292	43	86	6.7	19.2	88	172	934
1000	146	2.47	3.31	0.50	0.294	52	68	4.8	16.7	90	189	879
500	149	0.91	3.29	0.36	0.448	83	74	6.3	22.2	90	175	572
250	96	0.82	2.59	0.32	0.395	118	54	5.6	21.6	79	104	670
F value	6.5**	31.6**	51.7**	39.5**	16.2**	20.5**	56.8**	19.2**	3.0*	41.2**	7.5**	14.9**
LSD 0.01	110	0.45	0.93	0.14	0.084	344	19	1.5	4.9	25	135	74
LSD 0.05	146	0.59	1.23	0.18	0.111	454	25	2.0	-	33	179	97

* Without ^{137}Cs; ** With ^{137}Cs.

Table 3. Yields, ^{137}Cs, and mineral analyses of barley plants grown for 3 consecutive cuttings in Yolo loam soil with different pot sizes.

Pot size g soil	Yield mg/pot	K %	Ca %	Mg µg/g	P µg/g	Mn µg/g	Fe µg/g	Cu µg/g	Zn µg/g	Sr µg/g	^{137}Cs dpm/g
First cutting											
2000	2037	4.13	0.74	2662	3766	36	83	14.3	23.8	42	331
1000	1585	3.82	0.93	2668	2775	31	71	18.1	20.7	41	365
500	812	4.24	1.28	2691	3428	36	78	19.4	19.3	47	448
250	518	4.16	0.46	2595	3413	34	59	13.5	21.4	38	288
Second cutting											
2000	3106	4.05	1.61	3513	4325	61	97	29.6	24.6	57	671
1000	1891	3.90	1.40	3064	4030	64	82	27.9	29.3	56	715
500	724	3.91	1.23	2852	3822	69	86	26.0	25.4	49	501
250	383	4.23	1.33	3041	4243	76	86	19.0	26.3	51	381
Third cutting											
2000	2210	3.94	1.39	2913	3670	73	70	27.7	26.2	54	1969
1000	1194	3.48	1.41	2846	3119	62	70	24.3	24.2	55	1656
500	497	3.53	1.45	3103	3281	61	63	23.9	25.2	56	743
250	287	3.35	1.23	2864	3970	70	73	21.5	25.8	50	372
F value	82.8	0.4	7.6	4.8	2.2	7.5	5.4	5.1	1.7	4.9	102.3
LSD 0.05	192	-	0.24	234	-	12	9	4.7	-	5	47
Cuttings (Main Effects)											
1	1238	4.09	0.85	2654	3346	34	73	16.3	21.3	42	358
2	1526	4.02	1.39	3118	4105	68	88	25.6	26.4	53	567
3	1047	3.58	1.37	2932	3510	64	69	24.4	25.4	54	1185
LSD 0.05	N.S.	0.14	0.16	126	248	3	5	2.5	1.2	3	314
Pot sizes (Main Effects)											
2000	2451	4.04	1.25	3029	3924	53	83	23.9	24.9	51	990
1000	1557	3.73	1.25	2859	3308	52	74	23.4	24.7	51	912
500	698	3.89	1.29	2882	3510	51	76	23.1	23.3	51	564
250	396	3.91	1.01	2833	3875	60	73	18.0	24.5	46	347
LSD 0.05	286	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	4.5	N.S.	N.S.	451



Applied level of stable Cs, µg/g soil.

Fig. 1. Concentrations of ^{137}Cs in bush bean trifoliate leaves with different applied levels of stable Cs. In one case the stable Cs was applied together (.) with the ^{137}Cs and in another case they were applied separately (x) but uniformly mixed in either case.

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15. Supplementary Notes

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16. Abstract (Limit: 200 words)
The major objective has been to provide information that can help monitor low-level waste storage facilities. To accomplish this several small objectives were accomplished. (1) Capability for assay of several transuranic elements in sequence was developed at both UCLA and UCB labs. (2) Capacity to sample vegetation under statistically meaningful circumstances was further developed by a frequency distribution study of plants under reasonably uniform conditions. (3) Reasons for a several-fold range in the concentration ratios used to predict plant uptake of transuranium elements were demonstrated. (4) The objective of developing a more accurate multiple regression model of soil parameters on the concentration ratio of five different transuranium elements in plants involved in the food chain of man was pursued. (5) The objective of determining how much radionuclides can be mobilized by deep rooting of plants from depths in soil was put into an experimental test. (6) The relative importance of stable strontium vs calcium on radiostrontium transport and of stable Cs vs potassium on radiocesium transport under waste management conditions received study. (7) Several waste management soils were characterized (Fayette, Fuquay, Carjo and Puye). (8) Plans for Fy 1979 field plant work at Maxey Flats, Kentucky; review and synthesis of the data base relating to models and ideas used in the decision making processes and to verify and confirm old models but with parameters carefully identified and quantified were developed.

17. Document Analysis a. Descriptors

Low-level waste management, radionuclides, transuranic elements

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