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ECOLOGY SECTION

INTRODUCTION

THE LOS ALAMOS SCIENTIFIC LABORATORY RADIOECOLOGY PROGRAM WAS INITIATED IN 1972 TO SUPPLY INFORMATION ON THE ENVIRONMENTAL IMPACT OF THE LABORATORY'S RADIOACTIVE LIQUID WASTE DISPOSAL PRACTICES. THE SCOPE AND OBJECTIVES OF THIS PROGRAM, INCLUDING THE DESIGN OF SPECIFIC RESEARCH PROJECTS, APPEAR IN OUR FIRST ANNUAL REPORT TO THE AEC'S DIVISION OF BIOMEDICAL ~~AT~~ and ENVIRONMENTAL RESEARCH.[1]

THE PURPOSE OF THIS REPORT IS TO BRIEFLY SUMMARIZE CY73 PROGRESS ON TWO RESEARCH ACTIVITIES, NAMELY THE ENVIRONMENTAL RESOURCES INVENTORY AND THE RADIOECOLOGICAL STUDIES. A DETAILED ACCOUNT OF OUR RESEARCH EFFORTS WILL APPEAR IN THE NEAR FUTURE.[2]

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ENVIRONMENTAL INVENTORY

(T. E. Hakonson and W. C. Hanson)

A preliminary description of the Laboratory environment, including a listing of some of the associated plants and animals, was presented elsewhere.[1] Current environmental resource data includes a map (1:24000 scale) of the vegetation types, based on the dominant overstory species, for a 310 km^2 portion of Los Alamos County including the 120 km^2 occupied by the LASL. Color infra-red aerial photographs supplemented with field observations were used in identifying at least seven major vegetation types in the county. These types, from east to west, include Juniper (Upper Sonoran Life Zone); Pinon-Juniper, Ponderosa Pine/Pinon-Juniper, Ponderosa Pine-Fir (Transition Life Zone); and Limber Pine-Fir, Fir-Aspen (Canadian Life Zone). In addition, an open shrub-grass type of variable species composition occurs mostly within the Transition Zone.

Many of the woody and herbaceous species associated with the seven vegetation types have been identified. However, our herbarium contains nearly 350 individual plant species, attesting to the diversity of vegetation in the area and indicates the need for further work.

National Environmental Research Park Proposal

(W. C. Hanson)

A Proposal to Designate LASL Properties as a National Environ-

mental Research Park was drafted and presented to the LASL Director in November. The Proposal would provide for a comprehensive policy of land use; coordinate LASL engineering and research projects, and foster complimentary environmental investigations within LASL boundaries by other universities or agencies.

The designation of National Environmental Research Parks is a major new thrust of the USAEC. The principal objective of the Parks is to preserve representative parcels of land at each of the major AEC installations within the United States for long-term studies of various ecosystems. Such Parks have previously been proposed at Savannah River (South Carolina) and Oak Ridge (Tennessee).

The outstanding attributes of LASL that recommend its preservation and study as a NERP are: (1) the impressive diversity of ecosystems contained within its Upper Sonoran, Transition, and Canadian Life Zones; (2) three major canyons (Acid-Pueblo, DP-Los Alamos, and Mortandad) that have received liquid radioactive wastes especially cesium-137 and plutonium, during three different peri ods of time over the past 30 years; and (3) the recent designation of the Ecology Section within the Environmental Sciences Group, Health Division in July 1973. Radiation ecology studies at LASL began in July 1972, some 20 years later than those at several other USAEC installations, and have a challenging future.

A unique feature of the Park would be the preservation for study of

ecosystems that contain plutonium of various "environmental ages" in which studies of changing mobility of Pu may be sustained. The principal reservoir of plutonium is within alluvial soils in the canyon ecosystems; therefore, characterization of soils and radionuclide distribution within the various soil fractions is an important consideration in their description.

Characterization of Soils

(J. W. Nyhan and F. R. Miera)

Many of the alluvial soils in the waste discharge areas exist in deep canyons which have formed in the Bandelier Tuff since Pleistocene times. The original ash-flow tuff deposits, consisting of rhyolite ash and pumice with small amounts of quartz and sanidine crystals, have weathered to form the alluvial soils in the study areas.

Ten core samples were taken of the alluvium at each of 11 stations in Mortandad, DP-Alamos, Acid-Pueblo Canyons during the period May-July 1973. These core samples were frozen, cut into four segments (0-2.5, 2.5-7.5, 7.5-12.5, and 12.5-30 cm), oven dried, and characterized as to their particle size distribution, cation exchange capacity and soil pH.

More than 500 of these soil samples were mechanically separated

into six size fractions: silt and clay (< 53 μm diameter), very fine sand (53-105 μm diameter), medium and fine sand (105-500 μm diameter), coarse sand (500-1000 μm diameter), very coarse sand (1000-2000 μm diameter), and coarse fragments (2-23 mm diameter). Severely eroded and moderately eroded soil profiles in all canyons contained less than 1-2% silt and clay in the top 2.5 cm of soil, and less than 3-4% silt and clay in the remainder of the profile. Severely eroded soils contained up to 70% coarse fragments, whereas the dominant size fraction (up to 46% by weight) in most moderately eroded soils was very coarse sand. Only four of the 33 stations contained soils with minimal water erosion; these soil profiles contained up to 54% silt and clay, with increasingly smaller amounts of larger size fractions. They usually contained less than 10% coarse fragments (2-23 mm diameter).

The importance of adsorption and exchange of radioactive cations by the soil colloidal complex is well recognized; therefore, the cation exchange capacity of about 150 alluvial soil samples was determined. In general, increases in the cation exchange capacities of soil samples were correlated with increases in the smaller size fractions, especially soil particles smaller than 53 μm diameter. Thus, severely eroded, moderately eroded and minimally eroded soil profiles usually demonstrated cation exchange capacities of 3.8, 4-10, and 11-21 meq/100 g soil, respectively. Cation exchange capacity generally increased with soil depth, reflecting increased percentages of silt and clay beneath the 0.2.5 cm level in the profile.

Soil pH fluctuated as a function of distance above and below the waste outfall areas, partially due to the dumping of alkaline waste solutions. For example, values in Mortandad Canyon increased from about 6.6 at the pre-outfall station to a maximum value of 9.3, 320 m below the outfall, and then decreased to near the pre-outfall values at stations further downstream from the outfall. Very little change in soil pH was found with depth in any soil profile.

Arrangements have been made for a formal soil survey of LASL environs to be completed by USDA Soil Conservation Service scientists during early 1974. This will provide a detailed data base for future radiation ecology studies and for engineering and waste management operations.

Honeybees as Biological Indicators of Radionuclide Contamination

(T. E. Hakonson and K. V. Bostick)

Experimental results obtained during 1973 demonstrated that caged honeybees do not concentrate ^3H (as H_3O) above the levels measured in a supplied food (i.e., $\frac{\text{pCi } ^3\text{H/ml bee moisture}}{\text{pCi } ^3\text{H/ml food moisture}} \leq 1$). Therefore, the bees which exhibited unexpectedly high ^3H concentrations in body moisture during 1972[1] probably acquired the radionuclide

from a source which was at least equally contaminated with ^{3}H. The effluent liquid waste water in Acid-Pueblo (AP) and Mortandad Canyons did not contain sufficient ^{3}H to account for the levels of the nuclide observed in bees from the respective canyon environs.[1] Conversely, ^{3}H concentrations in DP Canyon water consistently exceeded the levels measured in a nearby bee colony. The fact that the bees were not equilibrating with the ^{3}H in effluent water from any of the canyons indicated that another source of the radionuclide existed in the environment.

Vegetation samples, in addition to bees and effluent water, were routinely collected since May 1973, both in the canyons and on the adjacent mesas where bees actively gathered nectar and pollen, to determine the potential of flowering vegetation as a source of ^{3}H to bees. Significant quantities of ^{3}H are released in gaseous effluents from the Laboratory[3] and it was anticipated that the vegetation might reflect these releases. In most cases, vegetation moisture samples contained ^{3}H concentrations which were at least equivalent to the levels measured in bee samples collected at the same time and in the same general location.

An increase from about 35 pCi ^{3}H/ml to 3500 pCi/ml in Mortandad Canyon bees during October 1973 could not be attributed to a corresponding

increase in the ^3H content of vegetation moisture in the general area around the canyon or to the liquid effluent entering the canyon. However, a large number of bees were observed in a stand of flowering white clover (Melilotus albus) in a fenced solid waste burial ground about 600 m from the Mortandad bee colony. Clover samples from the burial ground were measured to contain as much as 10^6 pCi H/ml.

The feasibility of using honeybee colonies as bio-indicators of ^3H in the environment will depend on several factors. First, the nature of the ^3H release will determine the potential pathway(s) of the material to the insects. At Los Alamos, where ^3H-contaminated liquid and gaseous effluents are both released to the environment, a gaseous effluent - vegetation - bee pathway is indicated by the data. Other pathways are possible (e.g., surface water - bee) and under a given set of environmental conditions they may become primal.

Experiments with caged bees at Los Alamos demonstrated that the insects rapidly reflect changes in the ^3H content of a food source due to a measured biological half-time of the radionuclide in bees of about one day. Consequently, sampling intervals need to be relatively short in order to detect rapid fluctuations in the ^3H content of any source.

The local climate in the geographical area will determine the length of time that the bees will actively gather food materials. In Los Alamos,

where we have a cool mountain climate, honeybees remain active for a 6-7 month period depending upon weather conditions.

The presence of flowering vegetation and natural or supplied surface water are requisites for establishing a honeybee colony. The foraging activities of a bee colony may cover as much as 190 km^2 depending on the availability of food items.[4] At Los Alamos, foraging bees have been observed in abundance nearly 2 km from the nearest hive.

Radiation Ecology Studies of Liquid Waste Disposal Areas

(T. E. Hakonson, W. C. Hanson, J. W. Nyhan, K. V. Bostick, and F. R. Miera)

The chronic input of low level radioactive liquid waste into Mortandad Canyon over the last 10 years has resulted in ^{238}Pu and ^{239}Pu concentrations which are 2-3 orders of magnitude higher than corresponding pre-outfall samples. Maximum concentrations in most samples occurred within 160 meters post-outfall and steadily declined with distance downstream. Concentrations approaching pre-outfall levels were measured at distances greater than 5120 m below the waste discharge point.

Highest concentrations ($\sim$ 300 pCi/g dry wt) of both Pu isotopes were observed in sediments. The concentrations of Pu in sediment core segments to sampling depths of 30 cm were relatively uniform

from the effluent outfall to 1280 m post-outfall where surface water exists at least part of the year. The plutonium in sediment samples beyond 1280 m where the stream channel is dry was increasingly concentrated in the top 2.5 cm.

There was an apparent distributional relationship between the ^{137}Cs concentrations in the 0-2.5 cm layer of post-outfall sediments and the corresponding data for ^{238}Pu and ^{239}Pu. A linear regression on the log transformed data provided correlation coefficients (r) of 0.97, n = 10 (^{137}Cs vs ^{238}Pu) and 0.88, n = 10, for ^{137}Cs vs ^{239}Pu. The interpretation of this observation is not clear at this time but may indicate that the distributive mechanisms for these two radionuclides may be similar in Mortandad Canyon sediments.

Maxima of 0.03 pCi ^{238}Pu/ml and about 0.001 pCi ^{239}Pu/ml were observed in surface water at the effluent outfall. Levels steadily decreased with distance downstream and approached analytical detection limits (0.05 pCi) for Pu at the 5120 m post-outfall sampling station. The plutonium levels in water averaged about 0.001 of the corresponding levels in sediment.

The concentrations of plutonium in vegetation followed a pattern with distance which was similar to that described for sediment and

water. Highest concentrations (5 pCi/g wet) were observed in grasses near the effluent outfall whereas shrubs and tree maxima were 1 pCi/g and 0.1 pCi/g, respectively. Concentrations in all plant types had decreased to pre-outfall levels ($<$ 0.04 pCi/g) at the [illegible] outfall sampling station. In general, the lowest growth forms (grasses) contained the highest plutonium concentrations. Grass/sediment activity ratios($\frac{\text{pCi/g dry plant}}{\text{pCi/g dry sediment}}$) of 8×10^{-2}(^{238}Pu) and 3×10^{-2}(^{239}Pu) were relatively high compared to values of 10^{-6}- 10^{-3} reported for the root uptake of Pu from plant-soil systems.[5,6,7,8] However, in Mortandad Canyon it is possible that the Pu was externally deposited on the grass samples and did not represent root uptake of the material.

The plutonium concentrations in the liver, lungs, hide and carcass of rodents from Mortandad Canyon varied by as much as 10^3 in samples from the same collection location. Mean plutonium concentrations were highest in the lung and hide samples, which suggested that resuspension of plutonium may have been an important mechanism of concentration. Post-outfall concentrations varied from about 8 pCi ^{238}Pu/g wet in the lungs of one rodent to about 0.01 pCi/g in other tissues. Concentrations of plutonium in control rodent samples measured 0.01 pCi/g or less. Liver and carcass samples from the contaminated area averaged 0.1-0.01 of the plutonium concentrations in hide and lungs. There was no apparent relationship between Pu concentrations in tissues of rodents and distance from the effluent outfall.

The $^{238}Pu/^{239}Pu$ activity ratios for the various sample types demonstrated that nearly all the samples contained a preponderance of ^{238}Pu. Throughout most of the period since 1969, when significant quantities of ^{238}Pu first appeared in Mortandad effluent, the activity ratio ($^{238}Pu/^{239}Pu$) in discharged effluent was about 4. Prior to 1969, nearly all of the plutonium discharged to Mortandad Canyon was ^{239}Pu. An activity ratio of about four was also observed in most sediment core segments, indicating that the relatively complete vertical mixing of ^{238}Pu has occurred within a three-year period.

Plutonium data for DP-Los Alamos and Acid-Pueblo Canyon alluvium samples are incomplete at this time, pending analyses of center and side channel samples. These data and additional data for Mortandad Canyon will be presented in a later report.

In summary, the stream channel sediments clearly are the major reservoir of the waste plutonium. The degree of mixing of plutonium in the alluvial sediments of the canyon appears to be associated with the presence or absence of surface water. Grass/sediment Pu concenration ratios of 0.03-0.08 were from 1-3 orders of magnitude higher than values reported for the root uptake of Pu in experimental plant -soil systems. The nature of the association of the Pu with vegetation is yet to be determined. Concentrations (pCi/g wet) of plutonium in rodents generally measured less than vegetation; however, some lung and hide samples exceeded levels observed in plants.

Cesium-137 in Soils of Waste Discharge Areas

(J. W. Nyhan and K. V. Bostick)

Cesium-137 determinations were performed on soil samples from various depths (0-2.5, 2.5-7.5, 7.5-12.5, and 12.5-30 cm) taken at the outfall station and at distances of 20, 40, 80, 160, 320, 640, 1280, 2560 and 5120 m downstream in all three waste discharge study areas (May-July, 1972). In general, maximum concentrations of cesium-137 occurred in the upper canyon areas, most of the cesium inventory having been deposited from 0-2560 m from the point of waste discharge. Maximum ^{137}Cs concentrations of 3258 and 1128 pCi/g dry soil occurred at 160 m in Mortandad Canyon (0-2.5 cm depth) and at 20 m in DP-Los Alamos canyon (2.5-5.0 cm depth), respectively. Minimum concentrations of about 10 pCi/g were found in both canyons 5120 m from the outfall station. Very little cesium-137 was detected in Acid-Pueblo canyon, most of the samples containing less than 2 pCi ^{137}Cs/g. A residual pocket of Cs-137 contamination was found 80 m below the outfall station and the cesium content of this soil sample was about 21 pCi/g (12.5-30 cm depth).

Several interesting trends were observed in distribution of Cs-137 with soil depth and in seasonal changes of soil cesium, as related to distance from the outfall stations in Mortandad and DP-Los Alamos Canyons. No significant changes in cesium concentrations

varying with soil depth were found at the outfall stations. However, in the upper portions of Mortandad (0-320 m) and DP-Los Alamos (0-80 m) canyons, higher levels of cesium occurred near the soil surface (0-2.5 or 2.5-7.5 cm) than deeper in the soil profile. In the lower portions of Mortandad canyon (1280-5120 m) there were significantly higher levels of ^{137}Cs at the 2.5-7.5 depth than elsewhere in the profile. Most of the soil samples from 160-5120 m below the outfall in DP canyon exhibited a general increase in cesium concentration with depth. The cesium-137 contents of soil samples from the study areas at two sampling times (October-November, 1972 and May-June, 1973) were compared to detect temporal changes in soil cesium. Increased levels were found in Mortandad (20, 80, 160 and 5120 m post-outfall) and DP-Los Alamos (40, 80, and 5120 m post-outfall) Canyons, reflecting relocation and laboratory waste additions of ^{137}Cs in these canyons.

Cesium concentrations in soils were correlated with soil pH and cation exchange capacity in several sampling stations in Mortandad and DP-Los Alamos Canyons. As the pH of soil samples taken in lower Mortandad Canyon gradually dropped from 9.3 (at 640 m) to 7.9 (at 5120 m), cesium-137 concentrations decreased from 833 to 1.1 pCi/g. The cesium-137 content of DP Canyon soil samples (2.5-7.5 cm depth) decreased dramatically from 617 to 17 pCi/g, between 80 m to 160 m below the outfall, as cation exchange capacity dropped from a maximum of 21

to 6 meq/100 g soil. Thus, decreased cesium concentrations were related to relatively acidic conditions and a low cation-holding capacity, which in turn was partially related to relatively low concentrations of soil particles less than 53 μm in diameter.

Cesium-137 determinations were performed on all 10 soil samples taken at every depth at 8 stations in Mortandad and DP-Los Alamos Canyons (0, 40, 640, and 2560 m post-outfall) to allow for estimates of statistical variation in soil cesium. The results of a preliminary statistical analysis of this data indicated: (1) significant differences in cesium levels as a function of soil depth at some sampling stations; (2) most of the Cs-137 data was either normally or log-normally distributed in the upper soil depths, but probably log-normally distributed at the lower soil depths; and (3) an increased variation in cesium concentrations with increased sampling depth but not with distance from the outfall station. Two-to-three-fold differences in cesium-137 concentrations were the most common, corresponding to coefficients of variation of 0.20 to 0.30. Increases in the CV to a maximum of 1.18 (DP Canyon, 40 m post-outfall, 12.5-30 cm depth) were observed frequently and are related to natural variations in the penetration depth of cesium into the soil profile.

Radiation Ecology Studies at Trinity Site

(T. E. Hakonson, W. C. Hanson, J. W. Nyhan, and K. V. Bostick)

A survey of the plutonium concentrations in soils, vegetation and rodents was conducted during September 1972 and September 1973 along the fallout pathway of the atomic bomb detonated at Trinity Site. Samples were collected from ground zero (GZ) and at 8 km increments out to a distance of about 56 km during 1972. Plutonium concentrations in samples along the fallout pathway were generally highest in the GZ area, were lowest about 24 km from GZ, and then generally increased in all sample types from 24 km to 56 km. Plutonium levels in GZ soils were as much as 10^4 times higher than the 0.01-0.1 pCiPu/g which has been reported for several New Mexico area soils.[9] A maximum of about 260 pCi Pu/g was observed at GZ in both the 0-2.5 cm and the 2.5-7.5 cm core segments. The maximum concentration in non-GZ soil (1.4 pCi/g) was measured in the 0.2.5 cm segment from the 56.4 km sampling station. Olafson et al.[10] also noted that the highest Pu concentration in non-GZ soils, vegetation, and small mammals occurred about 45 km from GZ.

The vertical distribution of Pu was relatively uniform to sampling depths of 30 cm ~~in most of the~~ core samples from GZ to the 24 km station. This suggested that Pu which was initially deposited on the soil surface as much as 27 years ago had migrated at least 7.5 cm into the soil profile. On the other hand, the Pu in soils from distances greater than 24 km was increasingly

concentrated in the upper 2.5 cm. Olafson et al.[10] and Olafson and Larson[11] reported that the Pu in Trinity area soils about 20 years ago was almost exclusively confined to the top 2.5 cm of soil. These differences were elucidated during September 1973 by hydrological experiments described below.

The Pu concentrations in grasses were consistently higher than similar measurements in other areas of New Mexico,[1,9] although Pu concentrations in forb and shrub-tree samples were generally indistinguishable from worldwide fallout Pu levels in New Mexico vegetation which measure about 0.001-0.005 pCi/g wet sample. The Pu data for grasses as a function of distance from GZ generally followed the pattern which was observed for the 0-2.5 cm soil core segment. The maximum Pu concentration in grasses (0.77 pCi/g wet) was observed at GZ and decreased to a minimum of 0.005 pCi/g at the 24 km station. Pu concentrations in grasses then generally increased with distance to the 56 km sampling station.

In general, rodent lungs had the highest mean Pu concentrations of all small mammalian samples and exhibited a pattern with distance from GZ that was similar to the 0-2.5 cm layer of soil and the grass. Lung deposition of Pu suggested that resuspension of soil may be an important mechanism in the biological redistribution of Pu. Other investigators have noted high lung concentrations in small free-roaming

mammals.[12, 13]

The activity ratios ($^{239}Pu/^{238}Pu$) for the 0-2.5 cm and 2.5-7.5 cm core segments averaged 19 and 18, respectively, while the 7.5-30 cm segment averaged 9. The mean values for vegetation were about 8-12 and about 0.5-2 for rodent tissues. The significance of the decreasing $^{239}Pu/^{238}Pu$ ratio from soils to vegetation to rodent tissues is not clear at this time. It may indicate that ^{238}Pu in the Trinity environs is more mobile than ^{239}Pu.

Results of this preliminary investigation indicated that the general pattern of Pu distribution in soils, vegetation, and rodents as a function of distance from GZ was similar to the findings of Leitch[5] and Olafson et al.[8] However, there has been an increased migration of Pu into the soils since the last measurements were made about 20 years ago.

In ~~October~~ September 1973, four permanent study sites were established in the Trinity Site environs to define Pu contamination patterns in soils and biota and to identify Pu transport pathways and mechanisms. Sites were chosen at 5.6 km south of GZ (Control Area); 1 km NE of GZ, an area of high-level contamination; 16 km NE of GZ, where an enhanced vertical migration of Pu was observed during 1972; and at 50 km NE of GZ, where the maximum concentrations in all sample types beyond GZ had been observed. Sampling techniques were designed to provide estimates of (1) the distribution of Pu within various soil size fractions and with depth and distance from GZ; (2) the variability of Pu concentrations in soils and vegetation; (3) the variability in plant biomass;

(4) water infiltration rates in various sites and soils; and (5) the Pu concentrations of ground-dwelling small mammals and passeriform birds.

Hydrological Characterization of Soils at the Trinity Site

(J. W. Nyhan)

The rate of water uptake by soils is one of the more important processes in the soil phase of the hydrologic cycle, which is important in determining the distribution of radionuclides in the soil profile. The amount of water that will enter a soil in a given time depends upon the amount of water that the soil can store and the rate at which the excess water is transmitted through moist soil to the wetting front in contact with the dry soil below. Soil properties governing water uptake rates are inherent in the genetic composition of the soil profile, such as the existence of soil layers with various particle size distributions, surface crusts, and soil structure.

Four determinations of water uptake rates were performed at each of the three intensive study areas located about 1, 16 and 48 km from Ground Zero of the Trinity Site. The average water uptake rates of these three sites was found to be 110, 192, and 92 mm/hr with coefficients of variation of 0.19, 0.19 and 0.08 respectively. A

comparison was made of the plutonium concentrations in soil samples taken close to these sites in 1972 with this hydrologic data. The soils of the 16 km site, which had a rapid water uptake rate (192 mm/hr), exhibited a 50% increase in the concentration of plutonium at the 0-2.5 cm depth (0.31 pCi/g) over that found at the 7.5-30 cm depth (0.21 pCi/g). Plutonium concentrations at the 0-2.5 cm depth (0.28 pCi/g) were 28 times higher than those at the 7.5-30 cm depth (0.01 pCi/g) in the 48 km station soils, where the lowest infiltration rate was observed.

Four soil cores to 60 cm depth collected at each study area for field capacity determination of the soils at various depths. Each soil profile receiveda measured addition of water and the amount of water held in the soil after excess gravitational water had drained away and the rate at which downward movement of water decreased was determined. These data will be included in a future report.

REFERENCES