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RADIONUCLIDES IN A DECIDUOUS FOREST SURROUNDING A SHALLOW-LAND-BURIAL SITE IN THE EASTERN UNITED STATES

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DISCLAIMER

Introduction

Information concerning the migration of radionuclides in the environment is needed for assessing the possible health and biological effects of radionuclides produced in the nuclear fuel cycle. A terminal point in the fuel cycle is the disposal of radioactive waste materials to a permanent repository. Ideally such a repository would prevent the interred radioactive materials from contacting the biological components of the terrestrial and aquatic environments over a period of time long enough for physical decay to reduce radioactivity to negligible levels. Because of long physical half-times, some radionuclides will persist for decades, others for centuries and a few for millenia. Land burial is an effective way to dispose of low level wastes because of the shielding properties that earth provides against external ionizing radiation. Land burial is also relatively inexpensive and if buried deep enough the materials would not be contacted by plant roots or by burrowing animals. If appropriately covered, burial trenches would not become deflated by wind and water action nor would rain water percolate through the trench covering and provide opportunities to move radionuclides downward to groundwater for possible transport beyond the burial site boundaries.

This study was initiated to determine if radioactive materials buried in trenches at the Maxey Flats burial ground in eastern Kentucky have migrated into the surrounding oak-hickory forest.

The Burial Ground

The burial ground is located at Maxey Flats, a 600 m wide flat-topped ridge in rural Fleming County, Kentucky (Meyer, 1976). The elevation of the ridge crest is about 310 m above mean sea level, rising

about 100 m above the surrounding valleys. The valley lands are under various kinds of crop management, i.e., row crops or pasture grass, but the adjacent steep slopes and ridge crests are covered by deciduous trees. The level portions of Maxey Flats have been deforested. The burial ground itself occupies about 40 acres and is completely enclosed by a chain link fence. Most of the ground inside the fence has been planted with perennial pasture grasses to help reduce soil erosion. The grass is periodically mowed, fertilized and seeded to discourage the self-establishment of volunteer tree seedlings and also for esthetic purposes.

The first radioactive waste material was buried in May, 1963 (Meyer, 1976). Solid wastes were usually shipped in 55-gallon steel drums or in wood or cardboard boxes and buried. Liquid wastes were solidified by mixing with cement and paper and the mixture was poured into polyethylene lined trenches. With few exceptions the wastes are buried in trenches 76-110 m in length, 6 m wide and 6 m deep. After filling, the trenches were covered with a minimum of 1 m of a mixture of native soil and rock. The backfill was compacted and shaped to encourage surface water runoff.

Because the annual precipitation at Maxey Flats averages 110 cm per year, water percolating through the trench cover is one of the important ways to move buried radionuclides away from the disposal site and possibly into the surrounding forest. By 1972 some of the completed trenches became filled or partially filled with rain water that had percolated into the trenches through the earth cover. A water management program was initiated to dewater the trenches. This consisted of pumping the water, storing it and then reducing the water volume by heat evaporation using buildings and equipment located on the burial ground property.

The movement of radionuclides from the burial trenches at Maxey Flats has several possible pathways. These include surface water runoff (spills), air dispersal of the steam plume originating from the operating evaporator facility and vertical and lateral water movements through the soil or movement through cracks or joints in the underlying rock strata. Biotic pathways could also provide a migration route, especially through deep rooted plants growing on and adjacent to trenches or by the activities of animals digging into the earth and exhuming buried wastes. Deeply rooted trees located downslope from the trenches might also tap contaminated subterranean water and bring radionuclides from below ground during the mineral uptake processes conducted by living trees.

Sampling in the Forest

The forest at Maxey Flats joins the burial ground boundaries on three sides (Figure 1). As a preliminary survey to determine if radionuclides associated with the burial ground were present in the forest, the forest floor litter was sampled. Litter was picked by hand from 18 places in the forest around the burial ground. A 0.32 m^2 circular plot was located on the ground between trees and all decaying leaves and humus were plucked by hand. Collecting was done in September prior to the onset of autumnal leaf fall. The litter was placed into plastic bags for shipment to Battelle Pacific Northwest Laboratories for oven-drying at 50-60°C and grinding. One hundred grams of milled, dry litter was counted for an array of gamma-emitting radionuclides using instrumentation described by Wogman et al. (1969). Two general kinds of radionuclides were associated with the forest floor litter. Endogenous (natural) radionuclides originating from the parent soil material and exogenous

(man-induced) radionuclides originating from the nuclear fissioning process, ^{60}Co and ^{137}Cs, are exogenous radionuclides and both are constituents of global fallout as well as being components of low level radioactive wastes stored at Maxey Flats. Potassium-40 and ^{228}Th are endogenous radionuclides originating from the underlying rock strata and soil.

Very low levels of radionuclides were measured in the forest floor litter (Figure 2). Cesium-137 and ^{60}Co were the most abundant radionuclides of exogenous origin and these have their origin in global fallout, which is ubiquitously distributed over all land surfaces. The variation among ^{228}Th, ^{40}K and ^{137}Cs radionuclides in the samples shows about the same pattern, but ^{60}Co content of the litter was much more variable, suggesting that the source of ^{60}Co measured in some of the forest floor litter samples is the burial ground itself rather than global fallout (Figure 2, Table 1).

After autumn leaf fall in early December, 18 places were sampled on the forest floor near the same places from which litter had been collected. Newly fallen leaves were collected by hand picking leaves from inside a 0.66 m^2 circular plot. These samples were treated in the same manner as litter and the results of radiochemical analyses are shown in Figure 2. The newly fallen leaves had about the same amount of ^{40}K and ^{228}Th as did litter samples. However, ^{60}Co content of newly fallen leaves was very low as compared to litter, with some samples having ^{60}Co levels below counting detection limits.

Because ^{60}Co could have appeared in newly fallen tree leaves by external absorption of airborne particles, it was decided to collect newly opened tree leaves in the spring to determine if ^{60}Co was present

within the physiologically active leaves. The range of values expresses as d/m/g dry tissue from three maple and three hickory trees collected in the vicinity of the evaporator facility in April, 1980 is shown below.

	Maple (d/m/g)	Hickory (d/m/g)
^{60}Co	<0.03-0.07	<0.05-4.0
^{137}Cs	<0.12-0.24	0.43-0.50
^{228}Th	<0.04	0.15-0.19
^{40}K	37-38	36-52

The leaves of one hickory tree had 4.0 d/m/g of ^{60}Co, suggesting that the source of ^{60}Co was the rooting substrate rather than airborne external contamination delivered by the steam plume from the evaporator facility. Hickory leaves also appeared to accumulate more ^{137}Cs and ^{228}Th than maple leaves.

To determine if individual trees had enhanced levels of ^{60}Co, leaves from separate trees were collected. Trees were marked with a metal tag nailed to the bole and three wire baskets, each 0.5 m^2, were placed around the trunk of each tree to collect the leaves as they fell during the period of leaf fall in the autumn of 1980. Baskets were set out in late September and emptied in early December. The average amount of leaf fall collected in the baskets was 364 g/m^2.

Mineral soil was collected beneath each tree after scraping away dead leaves and humus layers to expose the mineral soil. Potassium-40 was the most abundant radionuclide in the mineral soil (Figure 3). Cesium-137 and ^{228}Th were present in intermediate amounts and ^{60}Co was the least abundant. The cobalt content of newly fallen leaves was also more

variable than the other radionuclides, suggesting again that ^{60}Co was enhanced at only a few of the locations. This suggested that ^{60}Co was derived through migration from the burial ground. Most other trees were at background (global fallout) levels.

Potassium-40 was the most abundant radionuclide measured in newly fallen leaves, and there was relatively little variation between tree species or from location to location (Figure 3). Cobalt-60 and ^{137}Cs content of newly fallen leaves was much lower than ^{40}K. Cobalt-60 was present in measurable amounts in some leaf samples but not in others, again suggesting that the origin of some of the ^{60}Co was the burial ground.

An inventory of radionuclides in the soil, forest floor litter and newly fallen leaves in 1979 is shown below.

Sample Type	^{40}K	^{137}Cs	^{228}Th	^{60}Co
		($d/m/m^2$)		
Newly fallen leaves	1,200	177	75	78
Forest floor litter	4,800	3,800	500	700
Soil (upper dm)	2,800,000	426,000	250,000	52,000

These data indicated that on an areal basis (m^2) most of the radionuclides in the forest were associated with the surface soil, with relatively small amounts of radionuclides associated with the litter and the newly fallen leaves. Endogenous radionuclides ^{40}K and ^{228}Th dominated the radionuclides in the soil. Cesium-137 and ^{60}Co, exogenous radionuclides, were more abundant in litter than was ^{228}Th. Cesium-137 appeared to be retained in the litter layer, probably reflecting its airborne origin (fallout). Cobalt-60 has a relatively short half-life of about five

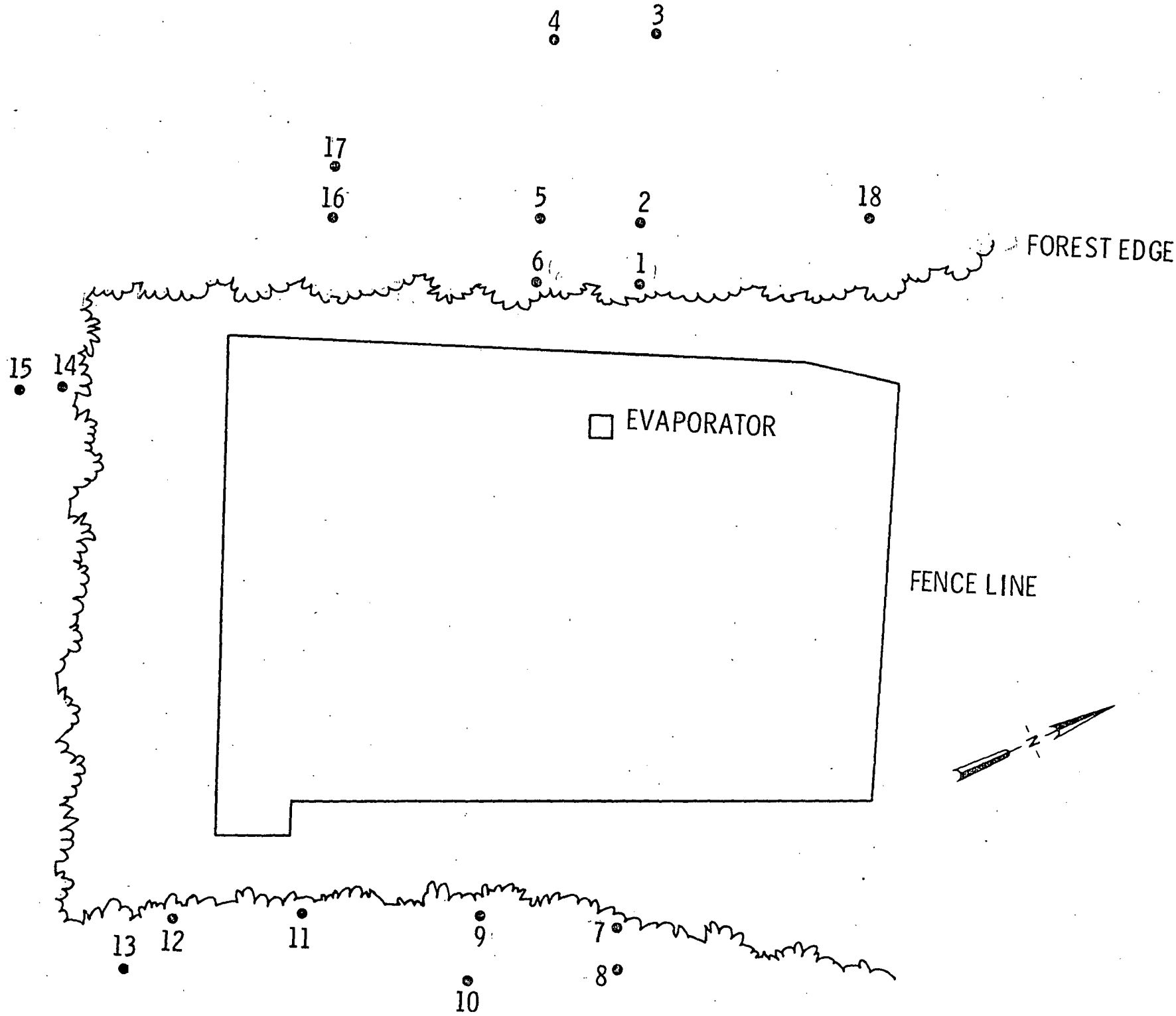
years as compared to about 30 years for ^{137}Cs and thus cannot be expected to persist in the forest floor for as long a time as ^{137}Cs. The reason for the migration of ^{60}Co is not entirely clear at this time but may be due to organic complexation with chelating compounds buried along with the radioactive materials, permitting ^{60}Co to be more mobile than other gamma-emitting radionuclides. Tritium and ^{14}C analyses are being conducted in plant sap and wood. Results will be presented at a future time.

Captions for Figures

Figure 1. Map showing the boundary of the oak-hickory forest in relation to the burial site at Maxey Flats, Kentucky.

Figure 2. Radionuclide content of leaf litter and newly fallen leaves at Maxey Flats, Kentucky in 1979.

Figure 3. Radionuclide content of soil and newly fallen leaves beneath individual trees at Maxey Flats, Kentucky in 1980.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FOREST EDGE
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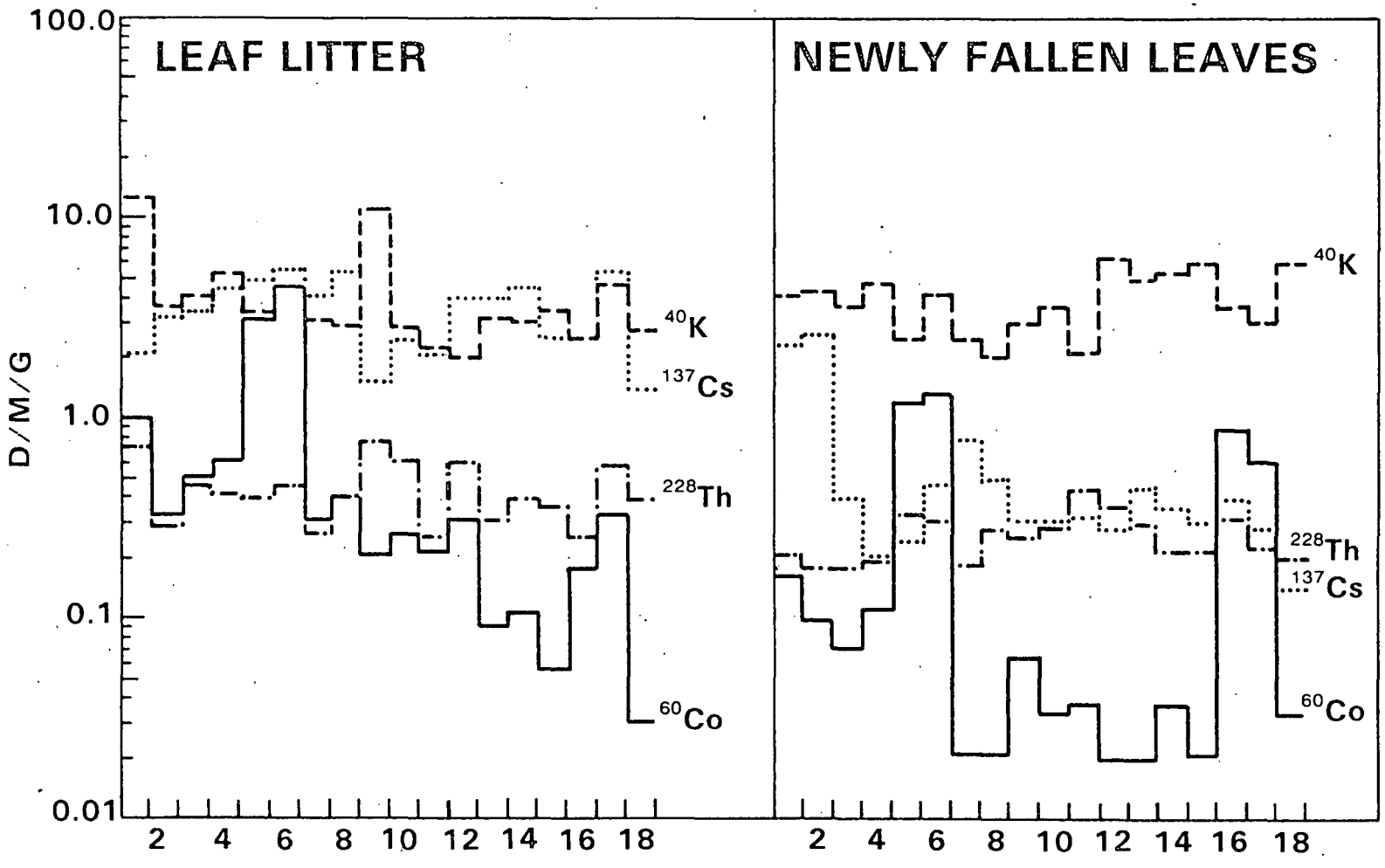
Figure 1.


LEAF LITTER
NEWLY FALLEN LEAVES
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10.0
1.0
0.1
0.01
2 4 6 8 10 12 14 16 18
^{40}K
^{137}Cs
^{228}Th
^{60}Co

Figure 2.

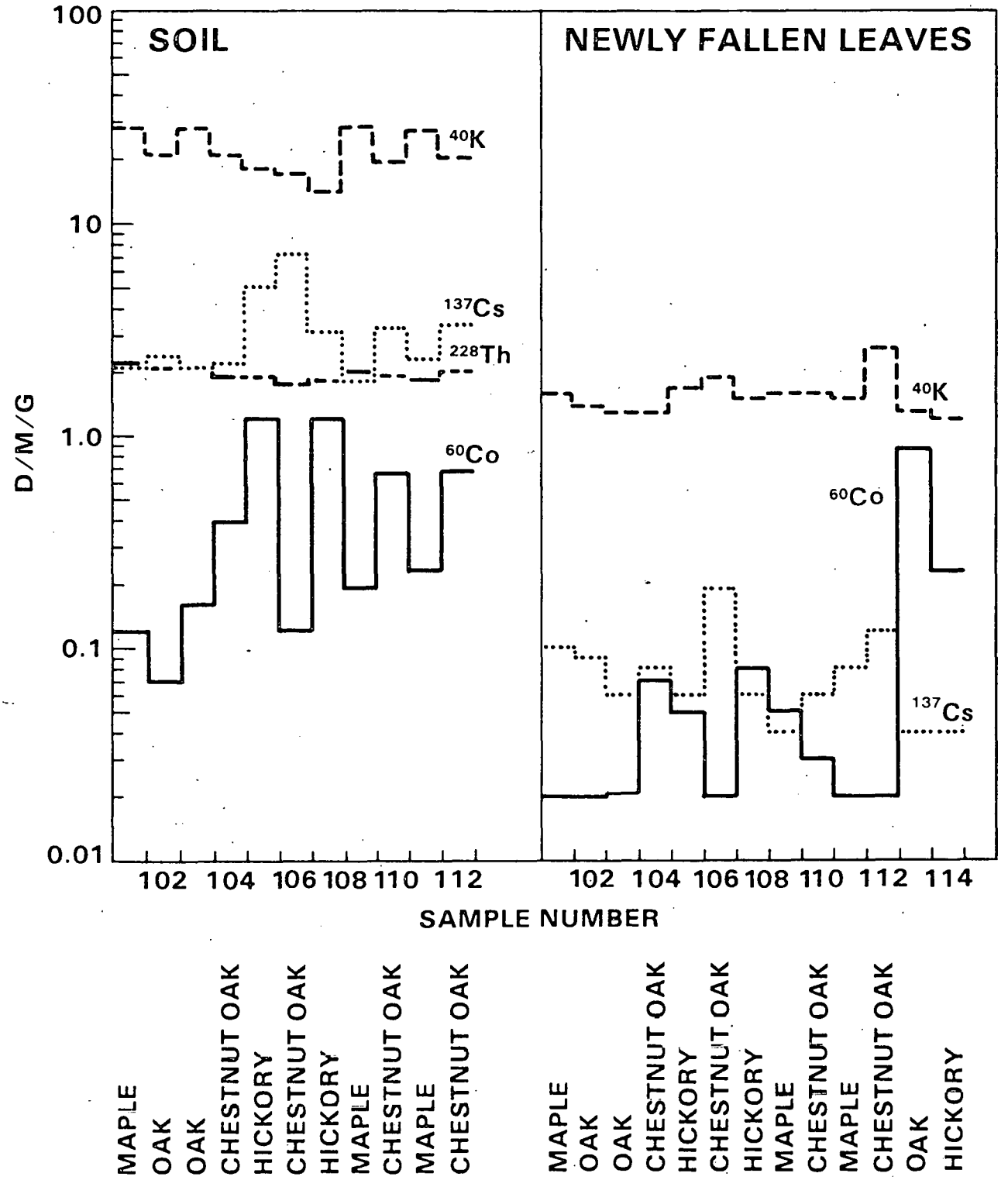
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Figure 3.

TABLE 1. Mean values and coefficient of variation (C_v) of radionuclides (d/m/g) in soil, litter and newly fallen leaves at Maxey Flats, Kentucky.

	^{40}K	^{137}Cs	^{228}Th	^{60}Co
Soil (mean)	21.96	3.14	1.95	0.458
C_v	0.22	0.52	0.077	0.92
Litter (mean)	4.36	3.46	0.45	0.70
C_v	0.66	0.38	0.36	1.68
Leaves (mean)	4.00	0.61	0.26	0.27
C_v	0.32	1.19	0.27	1.63

Literature Cited

Meyer, G. C. 1976. Preliminary data on the occurrence of transuranium nuclides in the environment at the radioactive waste burial site Maxey Flats, Kentucky. Proceedings of a symposium San Francisco 17-21 November, 1975 Jointly organized by USERDA and IAEA. Transuranium nuclides in the environment. International Atomic Energy Agency, Vienna. pp. 231-271.

Wogman, N. A., R. W. Perkins and J. H. Kaye. 1969. All sodium iodide anti-coincident shielded multidimensional gamma-ray spectrometer for low activity samples. Nuclear Instruments and Methods 74:197-212.

RADIONUCLIDES IN A DECIDUOUS FOREST SURROUNDING A SHALLOW LAND BURIAL SITE IN THE EASTERN UNITED STATES

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INTRODUCTION

Shallow land burial has been used to dispose of low-level radioactive wastes in various climatic regions of the United States. The burial site at Maxey Flats, Kentucky is located in a relatively wet climate that naturally supports deciduous forests.

OBJECTIVES

To determine if radionuclides buried in trenches at the Maxey Flat disposal site have migrated into the adjacent forest.

METHODS

Radiochemical analyses have been performed on forest floor litter, soil and freshly fallen leaves using gamma-ray spectroscopy.

RESULTS AND CONCLUSIONS

Endogenous (natural) and exogenous (manmade) radionuclides occur in forest samples at very low levels. Exogenous radionuclides Cesium-137 and Cobalt-60 occur in global fallout originating from nuclear weapons tests and these are measurable in forest samples. Only ^{60}Co appeared to be derived from the burial ground. The migration of ^{60}Co into the forest may have occurred from minor spills on the soil surface and been transported downslope into the forest by surface water runoff. An alternate route is migration by subterranean water movement from the trenches and root uptake of radionuclides by trees downslope from the disposal site. Investigations are continuing.

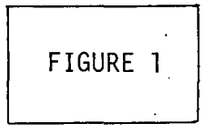

FIGURE 1. Map showing the location of the forest at Maxey Flats and the approximate locations of litter collection sites.

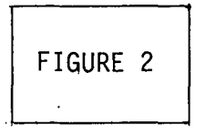

FIGURE 2. Radionuclide content of forest floor litter and freshly fallen leaves, 1979.

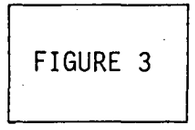

FIGURE 3. Radionuclide content of soil and freshly fallen leaves beneath individual trees, 1980.