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Radionuclide Concentrations in Wildlife Occurring at a Solid Radioactive Waste Disposal Area

Abstract

Of 18 mammalian species observed during a 24-month period at a solid radioactive waste storage and disposal area in southeastern Idaho, deer mice had the highest concentration of radionuclides (^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, and ^{241}Am) in tissues. Cottontail rabbit carcass samples from the disposal area had significantly greater concentrations of ^{241}Am than carcass samples from a control area. Background levels of radionuclides were detected in horned lark, mourning dove, and sage grouse. Coyote fecal samples from the disposal area had significantly greater concentrations of ^{241}Am than those from a control area, probably due to their consumption of contaminated small mammals. Results of these studies indicate that the numerous species of wildlife that inhabit the solid radioactive waste disposal area do not contribute significant quantities of radionuclides to the surrounding environment.

Introduction

The world's largest complex of nuclear reactors, a nuclear fuel reprocessing plant, and other associated testing and training facilities are located on the 230,000 ha Idaho National Engineering Laboratory (INEL) in southeastern Idaho. Since 1952, solid waste contaminated with activation and fission radionuclides from these facilities has been disposed below ground at the Radioactive Waste Management Complex (RWMC) of the INEL. In addition, transuranic waste from the U.S. Department of Energy's Rocky Flats facility in Colorado has been disposed or stored at the RWMC since 1954.

Shallow land burial is currently the most common method for disposal of solid low-level radioactive waste in the United States. In order to assess the environmental consequences of such disposal, data are needed to estimate radionuclide transport processes and migration rates. One potential mode of radionuclide transport is through invertebrate and vertebrate species that reside in, or travel through, radioactive waste disposal areas. Radionuclides may be assimilated when these species ingest other animals, vegetation, or soil and through inhalation and attachment of contaminated soil particles to skin, hair, or feathers. Radionuclides could be transported when animals disperse or migrate from the area or through predator-prey food webs (Arthur and Markham 1982a). Also, burrowing animals could excavate contaminated soil to the surface (Arthur and Markham 1983) which could be further transported by wind and water (Markham *et al.* 1978).

The purpose of this paper is to compare radionuclide concentrations in tissues of common vertebrate species. Information obtained from this and other radiological research projects conducted in the RWMC area will be utilized to determine the overall role of wildlife species in radionuclide uptake and transport at the low-level radioactive waste disposal area.

Study Area

The INEL is located in a cool desert shrub biome with warm and dry summers and cold, dry winters. Annual average temperature is 5.6°C with recorded extremes of 39°C and −47°C. Average annual precipitation is 22 cm, the

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majority accumulating in late spring and winter. Geologic features consist of successive subsurface basalt flows and interbedded sediments overlain by 1.0 to 7.6 m (average 5.0 m) of lacustrine and eolian deposits. Soil materials are unconsolidated clay, silt, and gravel.

The RWMC (elevation 1527 m) occupies 55 ha of the INEL and consists of two areas, the Transuranic Storage Area (TSA) and Subsurface Disposal Area (SDA). TSA is 19 ha in area; 8 ha was utilized for interim storage of transuranic wastes. The eastern portion contains some undisturbed big sagebrush (*Artemisia tridentata*) vegetation. A part of the SDA (36 ha in total area) has been seeded with crested wheatgrass (*Agropyron cristatum*); areas not seeded were invaded by Russian thistle (*Salsola kali*) and summer cypress (*Kochia scoparia*). Undisturbed areas peripheral to the RWMC are dominated by big sagebrush, bluebunch wheatgrass (*Agropyron spicatum*), and green rabbitbrush (*Chrysothamnus viscidiflorus*) (McBride *et al.* 1978).

Rodent species inhabiting the RWMC include 11 small mammal species (Groves 1981) of which the deer mouse (*Peromyscus maniculatus*), Ord's kangaroo rat (*Dipodomys ordii*), and montane vole (*Microtus montanus*) are the most common. Pygmy rabbit (*Sylvilagus idahoensis*), Nuttall's cottontail rabbit (*Sylvilagus nuttallii*), black-tailed jackrabbits (*Lepus californicus*), and horned lark (*Eremophila alpestris*) also occur at the RWMC. Commonly occurring game species include mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), sage grouse (*Centocercus urophasianus*) and mourning dove (*Zenaida macroura*). The most common predators in the area include the long-tailed weasel (*Mustela frenata*), coyote (*Canis latrans*), rough-legged hawk (*Buteo lagopus*), golden eagle (*Aquila chrysaetos*), and the great horned owl (*Bubo virginianus*).

TSA storage consists of metal drums or fiberglass-coated wooden boxes stacked aboveground on an asphalt pad. Plywood, plastic, and at least 0.9 m of soil covers the waste when pad areas become full. In SDA, wastes packaged in boxes, plastic-wrapped parcels, or uncontained are disposed by shallow-land burial practices. A greater potential for radionuclide migration is inherent in SDA disposal compared with storage at TSA because of different operational methods, use of different containers, and the duration of waste confinement. Therefore, in this paper, emphasis is given to radionuclide migration from the SDA disposal area rather than from other areas at the RWMC.

A wide variety of activation, fission, and transuranic wastes have been disposed in the SDA. Low-level activation and fission wastes are disposed in trenches which average 275 m long by 3 m wide, and approximately 4 m deep. These wastes consist of laboratory equipment, filters, paper, protective clothing, and building materials. Larger, irregular shaped material (pipes, empty liquid tanks, and other noncompactible items) are disposed in pits which average 30 m wide and 4 m deep, and vary in length. Transuranic waste disposed prior to 1971 was enclosed in steel drums or cardboard cartons; wooden crates were used for large items. Most transuranic waste was buried in pits, although some earlier shipments were interspersed in trenches with activation and fission waste. After pits and trenches are filled with waste, at least 0.6 m of soil is applied and compacted over the surface as a final cover.

Approximately 8.6 x 10^6 Ci of radioactive wastes have been disposed in the SDA since 1952. The current quantity of activity remaining in disposed waste is greatly reduced due to radioactive decay. No estimate is available of the quantity of specific radionuclides placed in the SDA prior to 1971; however, during the 1971-78 period 392 800 Ci of ^{60}Co, 4 104 Ci of ^{90}Sr, and 4 700 Ci of ^{137}Cs had been disposed in the SDA. Short-lived radionuclides frequently disposed include ^{51}Cr, ^{54}Mn, ^{58}Co, ^{59}Fe, ^{95}Zr, ^{103}Ru, ^{141}Ce, and ^{144}Ce. The major transuranic nuclides and the quantities placed in the SDA are ^{238}Pu (571 Ci), ^{239}Pu (21 050 Ci), ^{240}Pu (4 935 Ci), ^{241}Pu (179 000 Ci), and ^{241}Am (48 010 Ci).

Methods

Tissues from common wildlife species were sampled as part of other ecological studies at the RWMC (Arthur and Markham 1978) and analyzed for radionuclide concentrations. Deer mice, collected with museum special snap traps, were sampled for hide and carcass tissues; due to their small masses, tissues of at least four mice were composited for analyses. Hide and carcass tissues were sampled from cottontail rabbits (Janke and Arthur 1985). Muscle tissues of sage grouse

(Connelly and Markham 1982) and mourning dove (Markham and Halford 1982) were sampled and analyzed for radionuclide concentrations, whereas horned larks were analyzed whole. Coyote fecal samples were collected in and immediately adjacent to the SDA to estimate the quantity of radioactivity transported by a predatory species (Arthur and Markham 1982a). Tissue samples were also collected from wildlife species in control areas located at least 60 km from the SDA (off INEL), to assess radionuclide concentrations in wildlife not associated with radioactive waste disposal.

After dissection, all tissues were weighed (wet weight) and analyzed for gamma-emitting radionuclides on a 65 cm germanium-lithium detector coupled to a computerized multichannel analyzer system. Deer mice, rabbit tissues, and coyote fecal samples were dried for 72 hours at 80°C, weighed, and sent to a commercial laboratory for ^{90}Sr, ^{238}Pu, ^{239,240}Pu, and ^{241}Am analysis (Wessman *et al.* 1971). Lowest detectable concentrations (pCi/g wet weight) for commonly detected radionuclides were 0.09 for ^{90}Sr, 0.2 for ^{137}Cs, and 0.004 for ^{238}Pu, ^{239,240}Pu, and ^{241}Am.

A Student's t-test was used to determine whether radionuclide concentrations were significantly different between the SDA and control samples. A significance level of $P \leq 0.05$ was used for rejection of null hypotheses. Although ^{7}Be, ^{40}K, ^{208}Tl, ^{212}Pb, ^{214}Pb, and ^{214}Bi were frequently detected in tissue samples, no statistical analyses were performed on those radionuclides due to their natural occurrence in the environment.

Results

Deer mouse tissues had the highest radionuclide concentrations of the wildlife species collected at the SDA. Above background concentrations of ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and ^{241}Am were detected in hide samples, whereas the highest mean concentration of ^{90}Sr was detected in carcass tissues (Table 1). Elevated ^{90}Sr concentrations in carcass samples indicated that ingestion, and subsequent tissue assimilation, was a more important uptake mechanism than hide contamination.

Radionuclide concentrations in SDA cottontail rabbit tissues were not significantly ($P > 0.05$) greater than control area values with one exception. Americium-241 (0.01 pCi/g) in carcass samples was significantly greater than in control rabbit carcasses (0.001 pCi/g). The ^{241}Am concentrations in rabbit carcasses were similar to those detected in deer mouse carcasses. Fission nuclides (other than ^{90}Sr and ^{137}Cs) occurring in rabbit tissues included ^{51}Cr, ^{54}Mn, ^{60}Co, ^{134}Cs, and ^{140}Ba, each occurring in one SDA sample.

Horned lark, sage grouse, and mourning dove tissue samples from the SDA and control areas were analyzed for gamma-emitting radionuclides. No significant ($P > 0.05$) difference was observed between ^{137}Cs concentrations in 10 SDA (1.07 ± 2.51 pCi/g) and five control (0.21 ± 0.16 pCi/g) horned lark samples. Other fission products detected in horned larks were ^{60}Co and ^{137}Te, each detected in one sample. Comparisons between sage grouse muscle samples indicated no significant difference in ^{137}Cs concentration between the SDA and control population (Connelly and Markham 1982). Similarly, no significant difference was observed for ^{137}Cs concentrations in muscle samples of mourning dove (Markham and Halford 1982).

No coyote tissue samples were collected; however, 24 SDA and 12 control fecal samples were analyzed for radionuclides. No significant differences were observed between SDA and control area coyote fecal concentrations for ^{90}Sr, ^{137}Cs, ^{238}Pu, and ^{239,240}Pu; however ^{241}Am concentrations in SDA coyote feces (0.41 pCi/g) were significantly ($P < 0.05$) greater than control feces concentrations (0.008 pCi/g) (Arthur and Markham 1982a). Americium levels in SDA coyote feces were similar to levels detected in SDA deer mice tissues, indicating that ingestion of the small mammals was likely the source of americium in coyote feces.

Few samples were obtained from other SDA wildlife species. Cesium-137 concentrations ($\bar{x}$ = 0.32 pCi/g) in three rattlesnake (*Crotalus viridis*) carcass samples were at background levels; no other gamma-emitting nuclides were detected. Comparisons between three composite samples of invertebrates from the SDA, and one control area sample, indicated low radionuclide concentrations. Radionuclide concentrations detected in SDA invertebrate samples were 2.4 pCi/g ^{90}Sr, 0.47 pCi/g ^{137}Cs, 0.008 pCi/g ^{238}Pu, 0.078 pCi/g ^{239,240}Pu, and 0.022 ^{241}Am. No transuranics were detected in control samples; ^{90}Sr and ^{137}Cs concentrations averaged 0.7 and 3.7 pCi/g, respectively.

TABLE 1. Radionuclide concentration (pCi/g) in wildlife collected in and adjacent to the Subsurface Disposal Area and at control areas in southeastern Idaho.

				Mean Radionuclide Concentration ($\bar{x}$ + SD pCi/g)				
Species	Tissue	Area	Sample Size	^{90}Sr	^{137}Cs	^{238}Pu	$^{239,240}Pu$	^{241}Am
Coyote[1]	Feces	SDA	24	2.0 ± 1.6	3.4 ± 6.5	0.013 ± 0.027	0.5 ± 1.2	0.4* ± 0.9
		Control	12	0.9 ± 0.2	0.7 + 0.5	0.003 ± 0.004	0.006 ± 0.003	0.003 ± 0.002
Horned Lark	Carcass	SDA	9	---[6]	1.07 + 2.51	---	---	---
		Control	5	---	0.21 ± 0.16	---	---	---
Great Basin Rattlesnake	Carcass	SDA	3	---	0.32 ± 0.21	---	---	---
		Control	0					
Invertebrates	Composites	SDA	3	2.4 ± 3.2	0.47 ± 0.55	0.008 + 0.011	0.078 ± 0.11	0.022 ± 0.020
		Control	1	0.7	3.7	BDL	BDL	BDL
Deer Mice[2]	Carcass	SDA	21	721* ± 1061	57.3* ± 122	0.01 + 0.03	0.04 ± 0.11	0.01 ± 0.02
		Control	5	0.6 ± 0.6	0.20 ± 0.07	0.002 ± 0.003	0.002 ± 0.007	0.003 ± 0.002
	Hide	SDA	21	417* ± 612	78.5 + 132	0.54* ± 1.96	0.36* ± 0.66	0.27 + 0.83
		Control	5	1.3 ± 0.9	2.4 ± 0.5	0.002 + 0.002	0.007 ± 0.006	0.039 ± 0.050
Sage Grouse[3]	Muscle	SDA	14	---	0.3 ± 0.09			
		Control	20	---	0.3 ± 0.2			
Nuttall's[4]	Carcass	SDA	10	0.30 ± 0.24	0.14 ± 0.33	0.001 + 0.0004	0.004 ± 0.003	0.010* ± 0.009
		Control	5	0.37 ± 0.09	0.16 ± 0.12	0.001 ± 0.001	0.002 ± 0.001	0.001 ± 0.001
	Hide	SDA	10	0.45 ± 0.18	0.18 ± 0.15	0.002 ± 0.002	0.009 ± 0.010	0.029 + 0.046
		Control	5	0.44 + 0.15	0.31 ± 0.07	0.004 ± 0.003	0.002 ± 0.001	0.002 ± 0.001
Mourning[5] Dove	Muscle	SDA	12	---	0.63	---	---	---
		Control	11	---	0.75	---	---	---

[1]Arthur and Markham 1982a [2]Arthur *et al.* 1983 [3]Connelly and Markham 1982 [4]Janke and Arthur 1984 [5]Markham and Halford 1982

[6]Sample not analyzed for this radionuclide.

*Significant difference ($P \leq 0.05$) between SDA and control area concentration for this radionuclide.

Discussion

Data from this study provided information on the relative importance of certain vertebrates in radionuclide transport in the environment surrounding a low-level radioactive waste disposal area in southeastern Idaho. Due to their large biomass, small mammal species at the SDA such as deer mouse, Ord's kangaroo rat, montane vole, and Townsend's ground squirrel had the greatest potential for radionuclide assimilation and transport. Ingestion and hide contamination appeared to be the most important sources of elevated radionuclide concentrations.

Deer mouse tissues had the highest mean radionuclide concentrations of the wildlife species sampled at the SDA. Recent research indicated that an annual total of 22.8 μCi (^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and ^{241}Am) occurred in the deer mouse population inhabiting the SDA (Arthur *et al.* In press), as compared to 0.1 μCi occurring in a deer mouse population of equal size at a control area. Population estimates were based on a minimum of 6160 deer mice inhabiting the waste disposal area over a 1-year period. Of that 22.8 μCi activity, 22.7 μCi was due to the nuclides ^{90}Sr and ^{137}Cs.

Because deer mice were estimated to comprise 31 percent (106 of 346 kg live-weight) of the SDA total rodent biomass (Groves and Keller 1983), the estimate of 22.8 μCi transported by deer mice is only a portion of the total radioactivity in the SDA rodent population. By assuming that the other nine rodent species trapped in the SDA had tissue radionuclide concentrations similar to deer mice, a total of 73.5 μCi would occur in the SDA rodent population (Arthur and Markham 1982b). Even though the inventory for SDA rodents is higher than that for the control area, the overall quantity of radioactivity transported by these species is small.

In addition to rodent species, cottontail rabbits also commonly inhabit the SDA. Although a greater concentration of ^{241}Am occurred in carcass tissues of cottontails inhabiting the SDA, the total activity of radionuclides in the rabbit population at the SDA (11.2 nCi) was not significantly different from that estimated for control rabbits (13.2 nCi) (Janke and Arthur 1985).

The low use of the SDA by avian species is likely due to human intervention and because the SDA was dominated by crested wheatgrass, a vegetation type which has been shown to support fewer nesting species and fewer individual birds than sagebrush areas at the INEL (Reynolds 1978). Of the 31 bird species identified, tissues were collected from three common species. Neither horned lark, mourning dove, nor sage grouse tissues had significantly greater ^{137}Cs concentrations than control area values for these species.

An annual total of 7.2 μCi (^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and ^{241}Am) was present in feces eliminated by coyotes within a 6.3 km radius of the SDA, compared to a total of 1.8 μCi in feces eliminated by an equal number of coyotes in a control area (Arthur and Markham 1982a). Due to their limited use of the RWMC and the low quantity of radionuclides excreted by coyotes, it is doubtful that any environmental consequences occur as a result of this transport vector.

Previous studies have concluded that wildlife species can be modes of radionuclide transport in ecosystems having radioactive contamination (O'Farrell and Gilbert 1975, Halford *et al.* 1981). Some wildlife species inhabiting the SDA had contacted areas of radioactive contamination and assimilated above-background levels of radionuclides in tissues. This was particularily true for species such as small mammals which burrow into areas of disposed waste and subsurface soil contamination (Arthur and Markham 1983). Larger mammals and bird species had radionuclide levels similar to that in control samples. Transport of radionuclides by coyotes occurs but is minimal. Only for cottontail rabbits, small mammals, and coyotes were estimates available on the quantity of radioactivity contained in tissues and/or exported. For these species a total of 80.7 μCi (^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and ^{241}Am) was contained in tissues or feces over a one year period.

More important than the occurrence of radionuclides in animal tissues or feces, may be the effect of these species on soil covers over disposed waste. Recent research concluded that over a one year period, small mammal soil excavations brought 11 700 kg soil containing 45 μCi radioactivity to the SDA surface (Arthur and Markham 1983). Additionally, burrowing may increase moisture infiltration rates into soil. Studies currently being conducted at the INEL will determine the impact of biotic intrusion on soils covering disposed radio-active waste and utilize this information to recommend stabilization techniques for shallow-land radioactive waste disposal.

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