Tritium and Radioactive Carbon (^{14}C) Analyses of Gas Collected From Unsaturated Sediments Next to a Low-Level Radioactive-Waste Burial Site South of Beatty, Nevada, April 1994 and July 1995

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CONTENTS

FIGURES

TABLE

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
cubic foot	0.02832	cubic meter
cubic foot	28.32	liter
cubic foot per minute (ft^3/min)	0.02832	cubic meter per minute
foot (ft)	0.3048	meter
inch (in.)	25.40	millimeter
inch per year (in/yr)	25.40	millimeter per year
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
tritium unit (TU)	3.2	picocurie per liter
percent modern carbon (pmc)	0.061	picocurie per gram of carbon

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)]+32. Degrees Fahrenheit can be converted to degrees Celsius by using the formula °C = 0.556(°F-32).

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

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Abstract

Tritium activities in water vapor and radioactive carbon (^{14}C) activities in carbon dioxide were determined in gas samples pumped from small-diameter air ports installed in a test hole within the unsaturated sediments next to a commercial burial site for low-level radioactive waste south of Beatty, Nevada. In April 1994, gas samples were collected from test hole UZB-2, which was drilled about 350 feet south of the southwest corner of the fence enclosing the burial site. The test hole is part of a study to determine the depth to which atmospheric air circulates through the unsaturated sediments at the desert site. Laboratory results completed in May 1995 show activities of tritium and ^{14}C were greater than expected, with measured tritium in the water vapor as high as 762 tritium units at a depth of 79 feet and measured ^{14}C in carbon dioxide as high as 1,700 percent modern carbon at a depth of 18 feet.

In July 1995, the uppermost five air ports in test hole UZB-2 were resampled. In addition, water vapor was collected for tritium analyses at a distant test hole, and water vapor for tritium analyses and carbon dioxide for ^{14}C analyses were collected from three depths at the research shaft about 200 feet north of test hole UZB-2, and at two shallow probes (depth of 5.5 feet) next to the fence enclosing the burial site. Analyses of samples collected in the upper 112 feet from test hole UZB-2 in July 1995 show the same distribution of tritium and ^{14}C as analyses of samples collected in April 1994, except that activities were somewhat greater in July. The greatest activities of tritium and ^{14}C were measured from a shallow probe next to the fence with activities of 29,400 tritium units and 517,000 percent modern carbon, respectively.

Introduction

In September 1993, a test hole (UZB-2) was drilled by the U.S. Geological Survey about 200 ft south of a research shaft at the southwest corner of a commercial burial facility for low-level radioactive wastes (figure 1). The burial facility is in the Amargosa Valley about 10 mi south of Beatty, Nev., where precipitation averages about 4 in./yr (Andraski and others, 1995). Depth to ground water at the site ranges from about 300 to 370 ft below land surface. The purpose of the test hole was to monitor changes in subsurface gas pressures in relation to atmospheric pressure changes and to determine the natural distribution of gases as a means for estimating the depth of atmospheric air circulation in the unsaturated sediments (Prudic, in press).

Test hole UZB-2 was drilled to a depth of 300 ft using the ODEX air-hammer drilling method (Hammermeister and others, 1985). Nominal 6-in. diameter casing was attached to the air hammer with a special shoe connected to the casing. The air hammer drills a hole about 8 in. in diameter, which is slightly larger than the outside diameter of the casing. The casing is advanced down the hole as the hole is drilled deeper and additional casing is added at the surface. Drill cuttings are returned to the surface through the inside of the casing using air to force the cuttings up the casing. Below a depth of 300 ft, the test hole was drilled using a tricone bit and air circulated to remove the cuttings because the steel casing used in the ODEX method broke at a depth of 200 ft. The test hole remained open while drilling below a depth of 300 ft and the hole was drilled to a total depth of 376 ft.

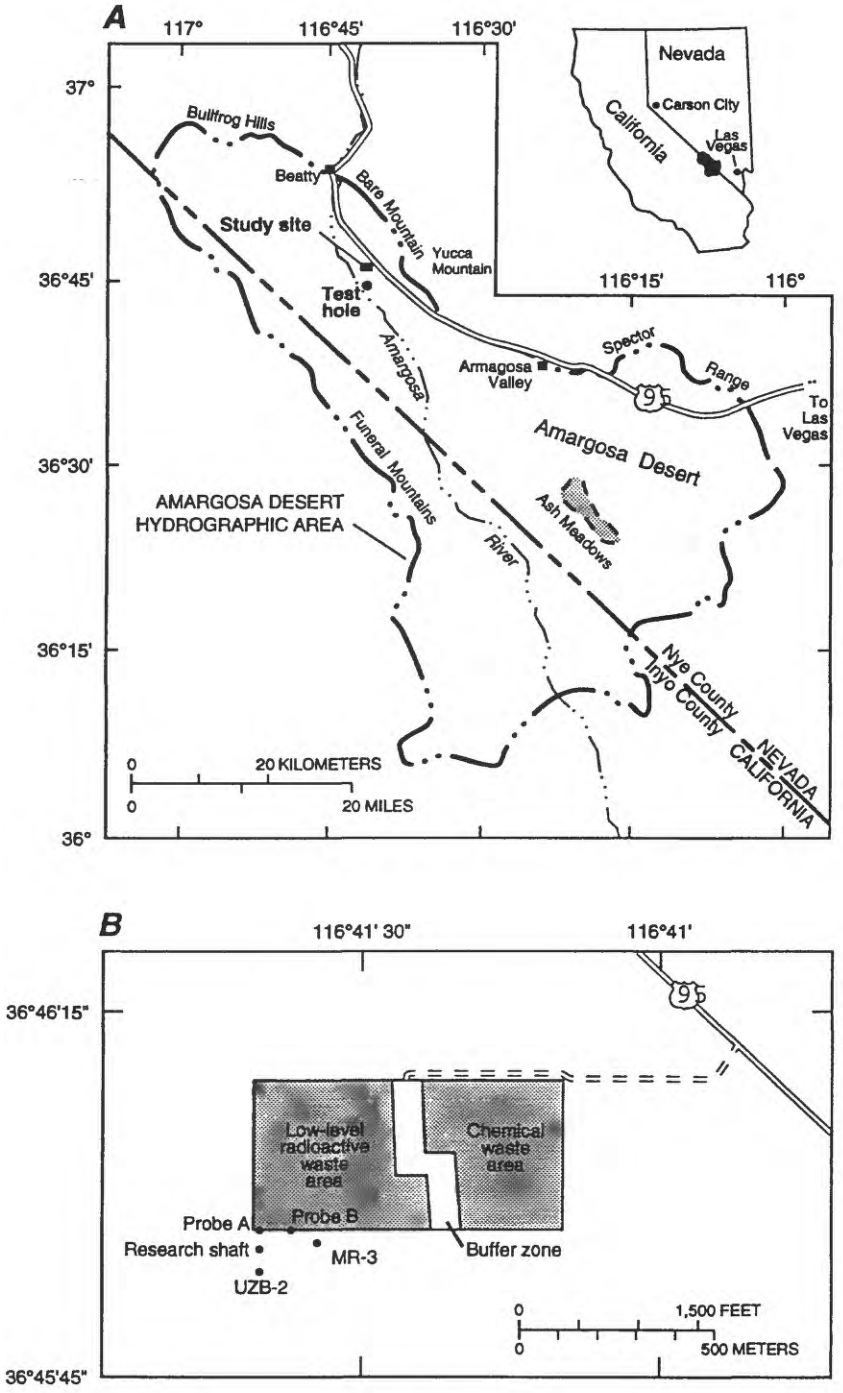

Figure 1. Location of (*A*) study site and distant test hole within the Amargosa Desert hydrographic area, and (*B*) sampling sites near low-level radioactive-waste burial area. Hydrographic area from Harrill and others (1988).

Ten air ports were installed in test hole UZB-2 as the hole was backfilled. Each air port consists of a 1-foot-long stainless steel screen that has an outside diameter of 0.9 in., and slotted openings of 0.008 in. in width.The screens are connected to nominal 1/4-in. diameter nylon tubing that extends to land surface. Depths to the midpoints of screens are 18, 39, 59, 79, 112, 157, 189, 309, 348, 357 ft below land surface. Each screen is placed within a 2-ft thickness of medium gravel. A mixture of sand, silica flour, and powdered bentonite was placed above and below each gravel layer. Bentonite grout was pumped into the hole above the mixture of sand, silica flour and powdered bentonite to seal the hole between screens. The uppermost 7 ft was filled with a neat cement grout. The broken length of casing between the depths of 200 and 300 ft was left in the hole. Bentonite grout was pumped around the upper and lower ends of the broken casing and the inside filled with sand. The upper 200 ft of casing was removed as the hole was backfilled.

The purpose of this report is to present the analytical results for tritium and radioactive carbon (^{14}C) in gas samples collected from test hole UZB-2 and from nearby locations.

Gas Sampling and Analysis

Each air port in test hole UZB-2 was pumped on four separate occasions between September 16, 1993, and April 14, 1994, and the gas analyzed for carbon dioxide. The total volume of gas pumped from each port prior to sampling for tritium and ^{14}C was approximately 3.5 ft^3 (100 liters). Carbon-dioxide concentrations seemed reasonably stable, suggesting that much of the air injected during drilling had been evacuated from the sediments surrounding each air port. Thus, between April 15 and April 20, 1994, gas samples were collected by continually pumping all ten air ports for almost 5 days at rates of less than 0.02 ft^3/min (less than 600 milliliters per minute). Samples for the determination of tritium in water vapor were collected by pumping the gas through a freeze trap immersed in a slurry of methanol and dry ice (Striegl, 1988), where the water vapor was frozen. Upon collection of sufficient volume of water, the ice was allowed to thaw and the liquid poured into glass vials and sealed. About 10 ml of liquid water was collected every 24 hours.The gas that past through the freeze traps from seven air ports was then bubbled through a gas-wash bottle containing 300 ml of 5-molar potassium-hydroxide solution (Striegl, 1988), where carbon dioxide was extracted. The gas was bubbled through the potassium-hydroxide solution for almost 5 days to obtain a sufficient quantity of carbon.

Tritium in the water samples was analyzed at the U.S. Geological Survey Water Resources Division isotope laboratory using the method described by Thatcher and others (1977), and ^{14}C activity in the carbon-dioxide gas was analyzed at the Radiocarbon Laboratory, Desert Research Institute, Las Vegas, Nev., using the method described by Haas and others (1983). Analyses of the April 1994 samples for tritium were completed in July 1994. Analyses of ^{14}C were completed in May 1995.

Because of greater-than-expected activities of both tritium and ^{14}C in the samples collected during April 1994, the uppermost five air ports were pumped again in July 1995 and water vapor and carbon dioxide for tritium and ^{14}C analyses were extracted from the gas. In addition, water vapor and carbon dioxide were extracted from gas pumped from three access ports at depths of 20, 36, and 43 ft inside the research shaft (Fischer, 1992), about 200 ft north of test hole UZB-2, and from shallow probes driven to depths of 5.5 ft below land surface adjacent to the fence enclosing the waste-burial area. Location of the research shaft and shallow probes is shown in figure 1*B*. Analyses for tritium were completed in August 1995 and those for ^{14}C were completed in October 1995.

Water vapor also was extracted from the two shallowest air ports at a test hole about 2 mi south of the research shaft. Location of the distant test hole is shown on figure 1*A*. Carbon dioxide previously had been extracted from all four air ports in June 1992 and analyzed for ^{14}C.

Results

Analytical results for tritium and ^{14}C in all samples are listed in table 1. The uncertainty with each activity presented in table 1 is one standard deviation of the counting methods used to determine tritium and ^{14}C activities, and thus, the uncertainty is a measure of the precision of the measurement. None of the results include uncertainties associated with sampling and processing. Activities of tritium in test hole UZB-2 are shown in figure 2*A*. Analyses of tritium from samples collected in test hole UZB-2 are similar for the 1994 and 1995 sampling dates, with measured peak activity at a depth of 79 ft. Tritium activities from samples collected in July 1995, however, are consistently greater than from samples collected in April 1994.

Table 1. Tritium in water vapor and carbon-14 in carbon-dioxide gas pumped from unsaturated sediments near burial site for low-level radioactive wastes south of Beatty, Nevada, June 1992, April 1994, and July 1995

[Location of sampling sites shown in figure 1. Symbol: --, not determined]

Depth (feet below land surface)	Date sampled	Tritium (tritium units)[1]	Carbon-14 (percent modern carbon)[2]
	Test hole UZB-2		
18	4/15-20/94	199 ± 5	1,700 ± 19
	7/09-10/95	249 ± 8	--
	7/10-11/95	253 ± 8	--
	7/11-12/95	240 ± 8	--
	7/12-13/95	247 ± 8	--
	7/13-14/95	243 ± 8	--
	7/08-14/95	--	2,160 ± 11
39	4/15-20/94	737 ± 10	--
	7/11-12/95	883 ± 12	--
	7/08-14/95	--	815 ± 5.1
59	4/15-20/94	581 ± 8	297 ± 3.5
	7/09-10/95	723 ± 11	--
	7/12-13/95	640 ± 12	--
	7/08-14/95	--	(3)
79	4/15-19/94	762 ± 10	199 ± 2.6
	7/10-11/95	1,100 ± 14	--
	7/08-14/95	--	201 ± 1.5
112	4/15-19/94	266 ± 10	--
	4/15-20/94	--	81 ± 1.2
	7/11-12/95	437 ± 9	--
	7/12-13/95	372 ± 9	--
	7/08-14/95	--	133 ± 0.90
157	4/16-20/94	198 ± 5	--
189	4/15-20/94	215 ± 5	28 ± 0.69
309	4/16-20/94	143 ± 5	--
348	4/15-19/94	133 ± 5	--
	4/15-20/94	--	22 ± 0.17
357	4/16-20/94	162 ± 6	--
	Distant test hole		
[4]34	6/05-09/92	--	101 ± 0.76
	7/09-11/95	3 ± 6	--
	7/11-12/95	0 ± 6	--
[4]41	6/05-09/92	--	90 ± 0.72
	7/09-10/95	5 ± 6	--
	7/10-11/95	-1 ± 6	--
61	6/05-09/92	--	78 ± 0.67
93	6/05-09/92	--	55 ± 0.75
	Research shaft		
20	7/11-12/95	92 ± 6	--
	7/12-13/95	92 ± 6	--
	7/09-14/95	--	(5)
36	7/10-11/95	619 ± 10	--
	7/12-13/95	615 ± 10	--
	7/09-14/95	--	(5)
43	7/12-13/95	229 ± 7	--
	7/09-14/95	--	(5)
	Shallow probe A		
5.5	7/09-10/95	8,980 ± 70	--
	7/09-14/95	--	451,000 ± 2,800
	Shallow probe B		
5.5	7/10-11/95	29,400 ± 210	--
	7/09-14/95	--	517,000 ± 2,100

[1] Tritium was analyzed by Robert Michel at U.S. Geological Survey Water Resources Division isotope laboratory, Menlo Park, California. Uncertainty associated with each tritium value represents the counting error at one standard deviation. Values from distant test hole are less than reported uncertainty. Measurement uncertainty does not include uncertainties associated with sampling or processing. Tritium units can be converted to picocuries per liter by multiplying with 3.2 (From Fritz, and Fontes, 1980, p. 14).

[2] Carbon-14 was analyzed by Herbert Haas at the Radiocarbon Laboratory, Desert Research Institute, Las Vegas, Nevada. Uncertainty associated with each carbon-14 activity represents the counting error at one standard deviation. Measurement uncertainty does not include uncertainties associated with sampling or processing. Percent modern carbon can be converted to picocuries per gram of carbon by multiplying with 0.061.

[3] Sample for carbon-14 was collected from air port at a depth of 59 feet in test hole UZB-2, and a value of 132-percent modern carbon was measured in laboratory. However, a leak was noted in tapered joint of collector and sample likely is contaminated with atmospheric carbon dioxide.

[4] Depths of uppermost two air ports not precisely known.

[5] Samples were collected in July 1995 from research shaft at depths of 20, 36, and 43 feet below land surface. Sample depths were not recorded on bottles; thus, individual sample depths are not known. Activities for the three depths are 3,580 ±25, 10,700 ±51, and 18,100 ±192 percent modern carbon.

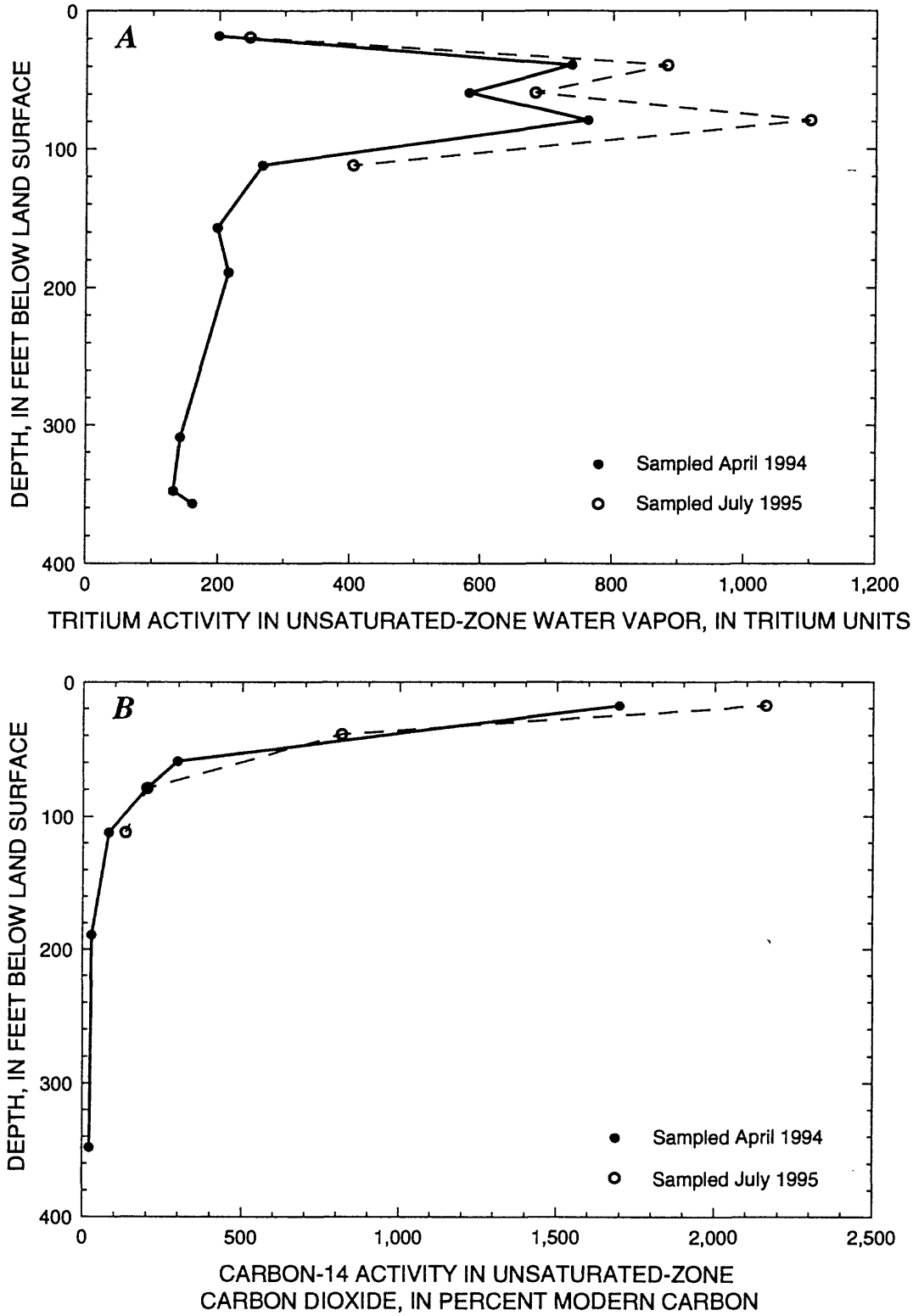

Figure 2. (*A*) Activity of tritium in water vapor, and (*B*) activity of ^{14}C in carbon dioxide from test hole UZB-2, next to burial site for low-level radioactive waste south of Beatty, Nevada, April 1994 and July 1995.

Tritium activities from samples collected at shallow depth near the fence that encloses the burial area are considerably greater than those at test hole UZB-2. In contrast, tritium activities from access ports in the research shaft are less than those measured in the test hole, although the activities are many times greater than the background activities measured from two air ports in the distant test hole (table 1). The lesser tritium activities from ports in the research shaft, when compared with those from test hole UZB-2, may be caused by atmospheric air circulation through the bottom of the shaft. The shaft was installed in a large-diameter bore hole (about 7 ft) to a depth of about 45 ft below land surface in 1983 and the surface around the shaft sealed with concrete (Fischer, 1992). However, the bottom of the shaft, which ended in sediments, was not sealed until the fall of 1993.

A sample of ground water was collected from test hole UZB-2 in September 1993 at the time the hole was drilled by lowering a bailer into the hole (the test hole was drilled several ft beneath the water table). This sample was sent to the laboratory for tritium analyses at the same time samples of the initial water vapors were sent. Tritium activity of the ground water was less than the detection limit of 3 TU (less than about 9.6 picocuries per liter).

Activities of ^{14}C for test hole UZB-2 are shown in figure 2*B*. Activities from four samples in the upper 80 ft at test hole UZB-2 are considerably greater than either the present-day (1994) ^{14}C activity in the atmosphere at Yucca Mountain (figure 1) of 115 pmc (Herbert Haas, Radiocarbon Laboratory, Desert Research Institute, Las Vegas, Nev., written commun., 1995) or the early 1960's peak activity in the atmosphere of the northern hemisphere of about 180 pmc (Broecker and others, 1980). The activities also are considerably greater than ^{14}C activities in four samples collected at the distant test hole (table 1). Measured activity of ^{14}C in test hole UZB-2 is less than atmospheric activities at a depth of 189 ft (table 1). The ^{14}C activity at a depth of 348 ft is nearly the same as the ^{14}C analyzed from a water sample collected in a nearby observation well (well MR-3 in figure 1*B*). The measured ^{14}C activity of ground water sampled from well MR-3 in August 1989 is 26 pmc.

Activities of ^{14}C from samples collected in July 1995 are greater than activities from samples collected in April 1994 at depths of 18 and 112 ft, and nearly the same at a depth of 79 ft. A sample was collected from the air port at a depth of 39 ft in April 1994 but the gas-wash bottle broke after sampling was completed while attempting to close a valve. Thus, the sample was inadvertently exposed to the atmosphere and, therefore, subsequently discarded. Similarly, a sample was collected from the air port at a depth of 59 ft in July 1995 and an activity of 132 pmc measured in the laboratory. However, a leak was noted in the tapered joint of the collector and thus, the sample likely was contaminated with atmospheric carbon dioxide.

Activities of ^{14}C in gas samples collected in July 1995 from access ports in the research shaft at depths of 20, 36, and 43 ft below land surface were greater than activities at comparable depths in test hole UZB-2. Measured activities from the access ports in the research shaft were 3,580, 10,700, and 18,100 pmc. However, sample depths were not recorded on the bottles for the ^{14}C samples and thus, activities at specific sample depths are not known. These activities are considerably less than those at shallow probes A and B next to the perimeter fence enclosing the burial area where ^{14}C activities are 451,000 and 517,000 pmc, respectively.

In summary, greater-than-expected activities of tritium and ^{14}C were detected in samples collected in April 1994 from air ports in test hole UZB-2. Activities of both tritium and ^{14}C in samples collected in July 1995 were greater closer to the burial site for low-level radioactive wastes than at test hole UZB-2. In contrast, activities in samples collected at a distant test hole were much less than those at test hole UZB-2. Samples collected in July 1995 from the uppermost five air ports in test hole UZB-2 show a similar distribution although activities are somewhat greater.

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