MOVEMENT OF RADIONUCLIDES IN UNCONSOLIDATED COASTAL SEDIMENTS AT THE LOW-LEVEL RADWASTE BURIAL SITE NEAR BARNWELL, SOUTH CAROLINA[1]

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ABSTRACT

A commercial low-level radwaste burial site is located in the southwestern part of South Carolina in a humid environment that receives about 1200 millimeters of precipitation annually. Radioactive waste is buried in the upper 10 meters of 13 meters of unsaturated Tertiary clayey sand. The Tertiary sediments are covered by aeolian sand which allows rain to readily percolate downward. Thickness of the aeolian sand ranges from a few centimeters to about 3 meters.

Analyses of core, water, and vapor samples indicate that tritium has migrated downward, outward, and upward from the buried waste. Water samples from monitoring wells within 3 meters of the buried waste contained tritium activity of over 100,000 picocuries per liter of water. Background activity of tritium in saturated and unsaturated sediments at the site is about 1,000 picocuries per liter of water. Cores of unsaturated sediments obtained within 3 meters of a trench wall contained tritium activity of more than 400,000 picocuries per liter of water. Tritium was detected in unsaturated sediment cores obtained beneath all trenches sampled. Cobalt 60 was the only other waste-product nuclide detected in any of the cores, and that was beneath only one trench.

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Air samples obtained about 20 millimeters above a trench cover indicate that tritium is moving upward from the waste into the atmosphere. Tritium activity in the air varies diurnally, reflecting the soil moisture evaporation rate. Tritium activity of 2,400 picocuries per liter of water condensed from the air was detected during night hours when evaporation was at a minimum. Tritium activity of 16,700 picocuries per liter of water was detected during daytime hours when evaporation was at a maximum.

INTRODUCTION

The commercial low-level radwaste repository is near Barnwell, South Carolina and located about 128 kilometers inland from the Atlantic Ocean, in the southwestern part of the State (fig. 1). The repository covers about 121 hectares and is one of three commercial burial sites for low-level radioactive waste presently operating in the United States. The property is owned by the State of South Carolina and is leased to and operated by Chem-Nuclear Systems, Inc. Chem-Nuclear has been licensed to bury waste at the site since 1971.

Radioactive waste is buried in the upper 10 meters of unsaturated Miocene sediments of the Hawthorn Formation. The unsaturated thickness ranges from about 7 to 13 meters. The burial trench bottoms are all 3 meters or more above the water table.

Radionuclides are transported away from the buried waste by at least two mechanisms. One mechanism is leaching by infiltrated precipitation and deep vertical percolation to the saturated zone. Radionuclides which enter the saturated zone move with the ground water toward nearby streams or wells, where they could eventually enter the biosphere. Diphasic radionuclides, such as tritium, can also be transported upward to the atmosphere by gaseous diffusion of water in the vapor phase within the unsaturated zone. Vapor moves upward from moist subsurface soil to replace moisture that has evaporated at the surface.

Sediments at the site are a sequence of unconsolidated clays and sands of Late Cretaceous and Tertiary age. These sediments are deposited over a graben that has been filled with Triassic sedimentary rocks. The upper clayey sediments average about 18 meters in thickness and are underlain by about 310 meters of

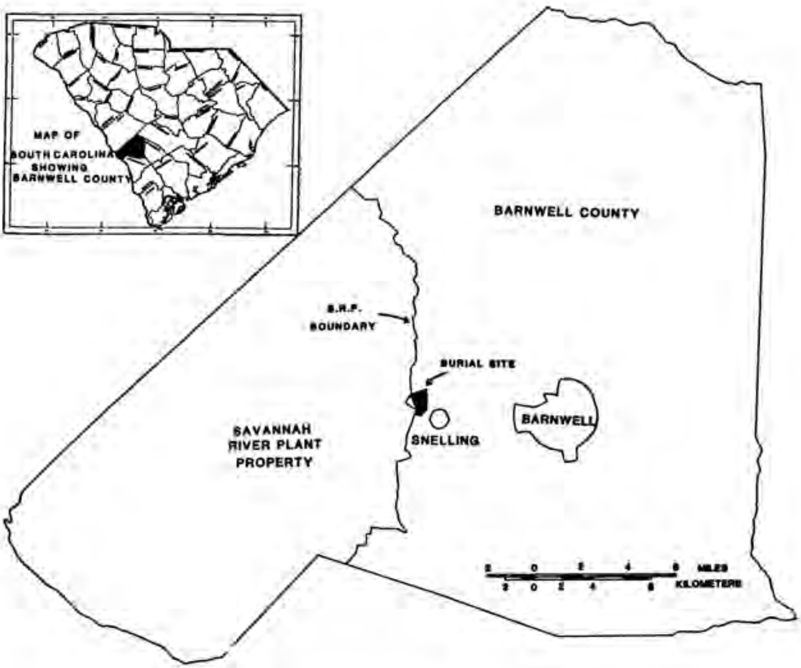

Fig. 1. --Location of low-level radioactive waste burial site.

medium to coarse sand that is interbedded with clays and silts. The lower 213 meters consist of Cretaceous sediments which are separated hydraulically from the above Tertiary sediments by a silty clay bed about 18 meters thick.

Hydrologic properties of the sediments were determined by laboratory and field tests. Laboratory hydraulic conductivity values ranged from about 10^{-8} to 10^{-1} m/d (meters per day) for the clayey sediments to about 7 m/d for aquifer sands. Field tests indicated transmissivity values of about 2,000 m^2/d (meters squared per day) for the Cretaceous sediments and about 560 m^2/d for the Tertiary sediments. Aquifer tests conducted at the burial site indicated poor hydraulic continuity between the Cretaceous and Tertiary sediments. Field tests indicated heterogeneity in the Tertiary sediments.

The repository is located in a humid environment that receives about 1200 millimeters of precipitation annually, with the greatest rainfall occurring in the summer months. Surface runoff from rainfall is negligible due to the nearly flat topography and the high permeability of the aeolian sand that covers the area.

Recharge to the ground-water system is from precipitation and discharge occurs mainly as seepage to a nearby stream. Streamlines drawn perpendicular to equipotential water levels indicate that most of the precipitation that infiltrates to the saturated zone at the site is eventually discharged as seepage into the creek south of the burial trenches (fig. 2).

Figure 2 depicts ground-water mounds in the southern part of the burial site. These mounds are caused by collection of perched water in depressions on the surface of the Miocene clayey sediments. Most depressions have elliptical geometric patterns which are known locally as "Carolina bays." Some of the bays are covered by surface sand which reduces evaporation, thus allowing a source of continuous recharge to the ground-water system.

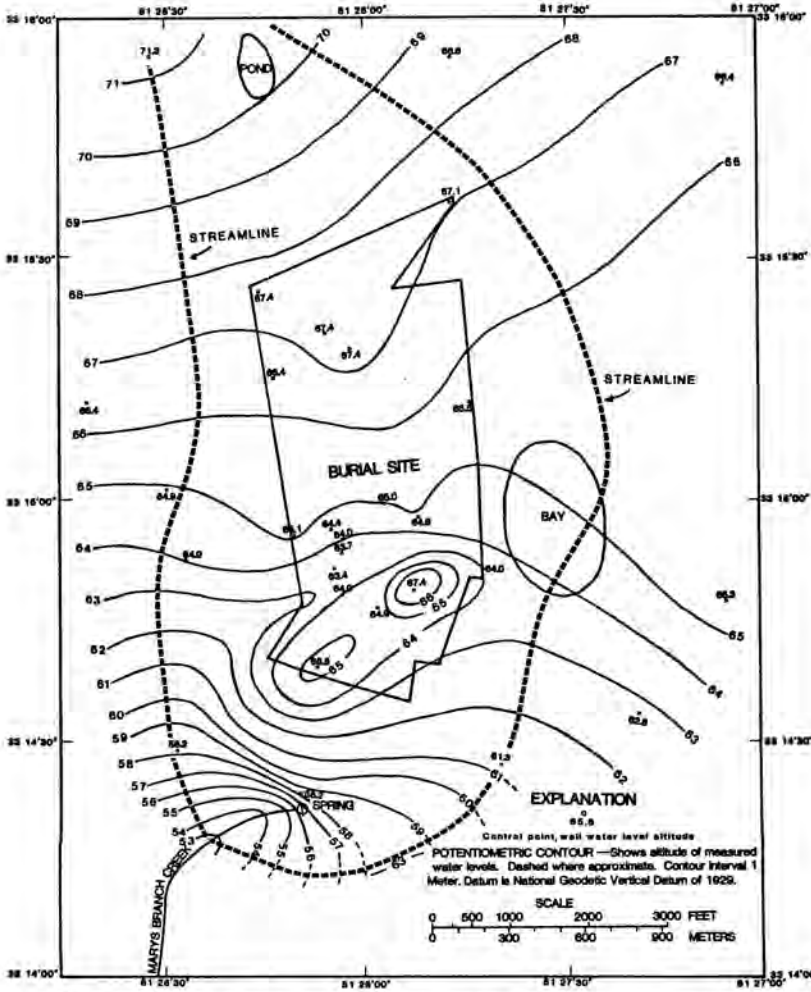

Fig 2.--Water-level contours of upper clayey sediments at the radwaste burial site during August 1981.

RADIOACTIVITY IN CORED SEDIMENTS

Sediment cores obtained during 1979 from beneath the buried waste showed evidence of radionuclide movement due to deep percolation. Tritium activity was detected in water extracted from unsaturated core samples obtained from beneath four trenches (fig. 3). Tritium activity was about 1 billion pCi/L (picocuries per liter of water) in sediments beneath trench 7 (locations shown in fig. 4) with only a slight decrease in activity with depth. Sediment cores from beneath trench 5 showed small changes in tritium activity with depth. Cores from beneath trench 2 showed a large increase of tritium activity from 9 to 11 meters. Tritium activity in core samples from beneath trench 8 decreased with depth, from about 100 million pCi/L at 9 meters to about 1 million pCi/L at 11 meters.

Cobalt 60 was detected only in core samples obtained from beneath trench 2. A cobalt 60 activity of about 690 pCi/gm (picocuries per gram of sediment) was detected about 0.15 meters beneath the trench floor and decreased to 2.4 pCi/gm at 1.78 meters. Cobalt 60 was not detected deeper than 1.80 meters below the trench floor.

Sediment core samples were obtained at depth intervals of 0.5 to 1.5 meters when monitoring wells were drilled adjacent to burial trenches. Moisture in all the cores contained tritium. Some cores obtained within 4 meters of the trenches contained tritium activity above the background levels of about 1,000 pCi/L. Figure 5 shows the variation in tritium activity with depth at seven observation sites. Sites CN-1 to CN-4 are all less than 4 meters from the buried waste and sites CN-5 to CN-7 are more than 45 meters from the waste (fig. 4). Tritium activity greater than one million pCi/L occurred about 3 meters below land surface at CN-4. Site CN-4 is about 3 meters south of trench 8 and is in the ground-water flow path from beneath waste buried since 1972. Sediments at CN-2 showed tritium activity of over 100,000 pCi/L at about 4 meters below land surface. The CN-2 site is located at the southeast end of trench 8 but not in the flow path from beneath the north trenches. Site CN-3, at the northeast edge of trench 8, showed no activity greater than background below the level of the trench floor (7 meters deep), which suggests that much of the tritium that escapes from trench 8 is carried by vapor movement. Site CN-1, located between trenches 13 and 15, also

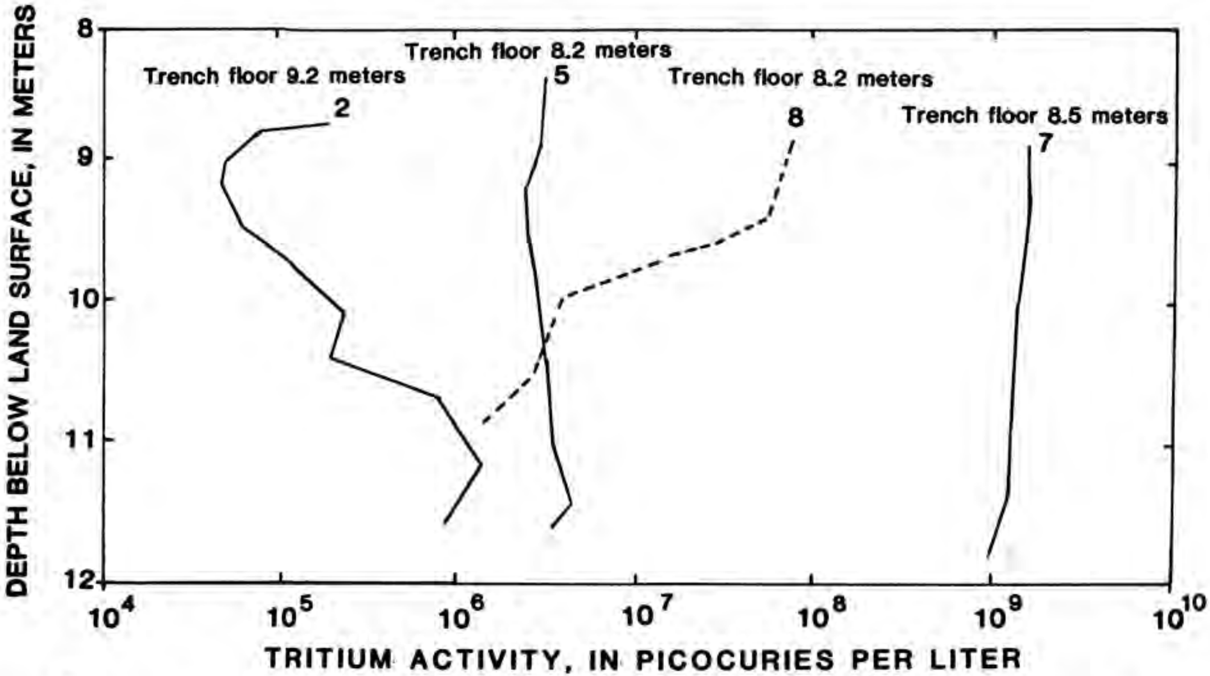

Fig 3.—Tritium activity in water extracted from core samples taken from beneath waste at the radwaste burial site.

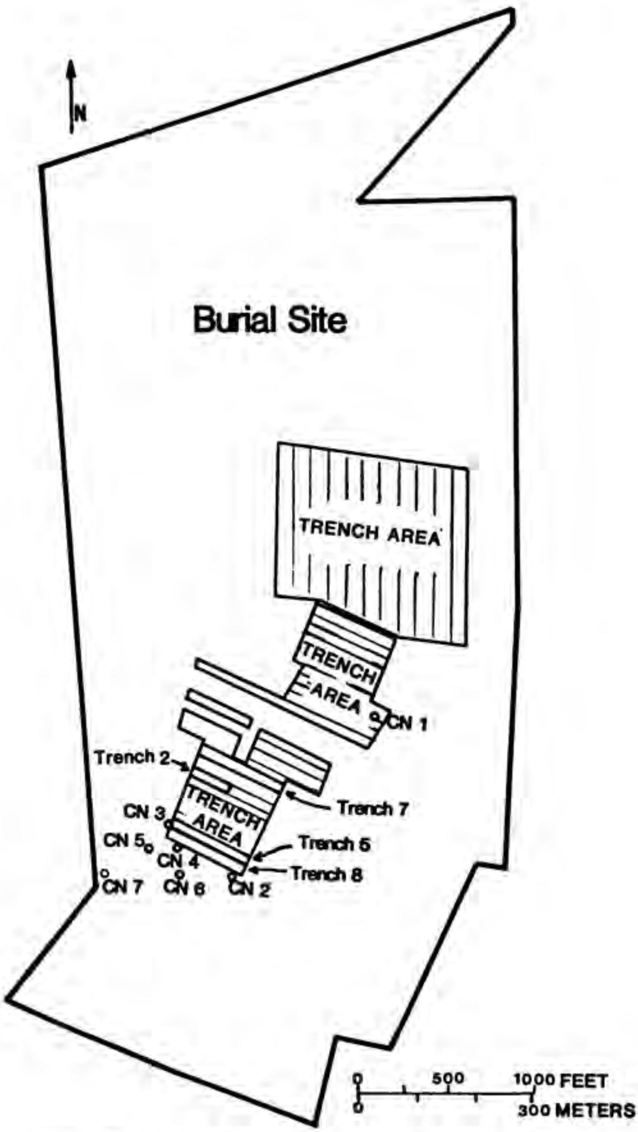

Fig. 4.--Location of sediment core sampling at the low-level radwaste burial site.

showed evidence of upward tritium movement in the vapor phase. Tritium activity of about 70,000 pCi/L occurred at about 1 meter below land surface and decreased to about background near the trench floors (about 7 to 8 meters deep).

Tritium may have migrated laterally more than 45 meters from the trench area. Sediments at CN-6 showed a slight increase in activity in the unsaturated zone at a depth of about 6 meters, possibly as a result of transport by vapor diffusion. This site is about 42 meters south of CN-4. About 75 meters southwest of the buried waste, at CN-7, there was a slight tritium increase between 16 and 18 meters. This increase occurred in the aquifer sand below the clayey sediments and suggests that the tritium was transported by ground water. Most of the lateral monitoring was conducted south of trench 8 because ground-water movement from the trench area is in this direction (fig. 2).

RADIOACTIVITY IN WATER SAMPLES

Ground-water samples are collected monthly at about 25 monitoring wells adjacent to the burial trenches. These wells are screened at the lower 3 meters and grouted with cement to the land surface. Site CN-4, 3 meters from the south end of trench 8, has two wells which are 13 and 21 meters deep (fig. 4). Sediment cores from the 13-meter depth at this site contained tritium activity of about 40,000 pCi/L of soil water when the wells were constructed in 1977. In 1980 tritium activity in water samples from the 13-meter well ranged from about 70,000 to about 173,000 pCi/L. In 1981, the water table declined, causing the 13-meter well at CN-4 to go dry. The 21-meter well at CN-4 did not show evidence of tritium acitvity above background until the fall of 1981 when about 116,000 pCi/L was detected in a water sample. Detection of tritium activity greater than 100,000 pCi/L in the deeper well strongly indicates the downward movement of radionuclides into the more permeable sands beneath the clayey sediments. A water sample from a well 2 meters east of trench 2 contained tritium activity of about 42,000 pCi/L during 1981. This well is screened in the lower sand unit at about 25 meters. Water samples collected from other monitoring wells contained tritium at background levels.

RADIOACTIVITY IN AIR SAMPLES

Air samples were collected over the center of trench 8 at different heights above the cover (fig. 4). Trench B was selected for air sampling because this site showed the highest tritium activity near the land surface (fig. 5).

Peristaltic pumps were used to pass the air through cold traps and the condensed water vapor was analyzed for radioactivity. Tritium was the only radionuclide detected in the water. Table I shows the tritium activity in air passed through the traps. Air samples collected 20 millimeters above the land surface showed tritium activity which ranged from 2,400 to 16,700 pCi/L. Tritium activity of 17,500 pCi/L was detected at a height of 600 millimeters during the daylight hours. Tritium activity generally decreased with height as indicated by the samples collected at 1000 millimeters. The greatest activity occurred during the daylight hours when evaporation was at a maximum.

SUMMARY

Data collected at the low-level waste repository near Barnwell, South Carolina, indicate that tritium is the principal radionuclide migrating from the buried waste. Sediment samples collected from beneath the buried waste showed tritium activity in excess of one million pCi/L. Sediment cores and well-water samples obtained at sites adjacent to the buried waste indicated that tritium has migrated laterally. Water samples from wells penetrating the sands beneath the clayey sediments showed that tritium has migrated downward to at least 25 meters.

Water extracted from sediments near the buried waste indicated that tritium has been transported upward to the land surface by gaseous diffusion in the vapor phase within the unsaturated zone. Air samples collected above the buried waste substantiate that tritium is entering the atmosphere at the burial site.

Radioactive cobalt 60 is the only gamma-emitting radionuclide detected away from the confines of the burial trenches. Cobalt 60 activity of about 690 pCi/gm was detected about 0.15 meters beneath the trench floor but no cobalt 60 activity has been detected deeper than 1.80 meters.

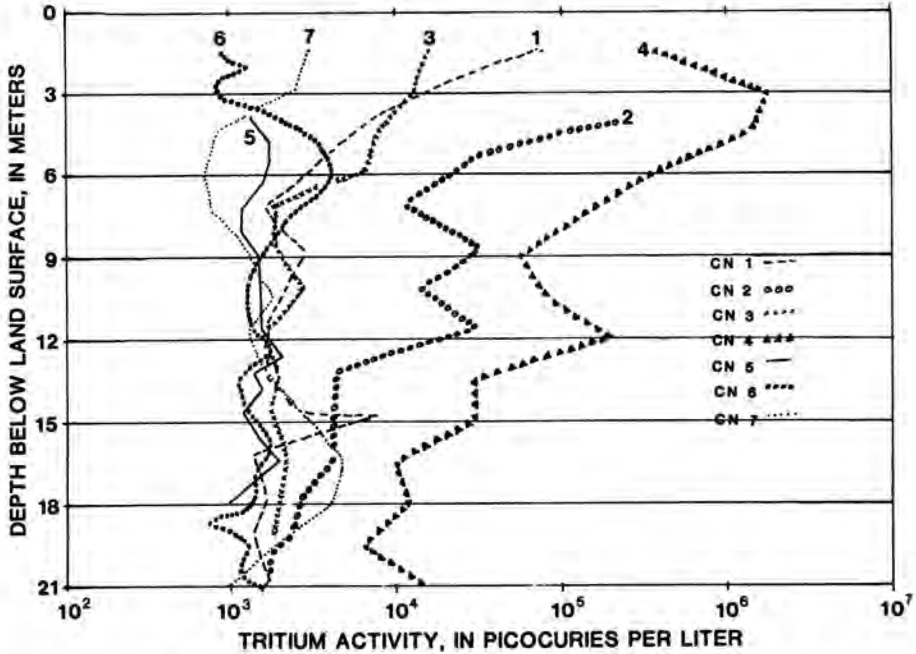

Fig. 5.--Tritium activity in water extracted from core samples taken at the radwaste burial site.

Table I. Tritium activity of air above land surface during September 9 through September 11, 1981 at the low-level radwaste burial site

Distance above land surface (milli-meters)	Hours of collection	Pumping rate (cubic centimeters per minute)	Volume of air pumped (cubic meters)	Relative humidity (percent)	Average air temperature (°C)		Tritium activity (picocuries per liter)
					dry bulb	wet bulb	
20	14:00	600	0.616	95	17.8	17.3	2,500
200	to	1,100	1.129	95	17.8	17.3	2,600
400	07:50	950	0.975	95	17.8	17.3	2,100
20	08:00	600	0.298	78	27.0	24.0	2,400
200	to	880	0.438	78	27.0	24.0	1,600
400	16:20	650	0.224	78	27.0	24.0	1,100
20	16:30	525	0.479	92	19.5	18.6	3,300
600	to	450	0.410	92	19.5	18.6	1,900
1000	07:40	300	0.274	92	19.5	18.6	1,800
20	08:00	820	0.098	93	25.5	24.6	16,700
600	to	650	0.078	93	25.5	24.6	17,500
1000	10:00	370	0.044	93	25.5	24.6	1,500