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TRITIUM MIGRATION STUDIES AT THE NEVADA TEST SITE

Topical Report
August, 1991

Prepared by: R. K. Schulz
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University of California

Work Performed Under Contract No. DE-AC08-89NV10755

Reynolds Electrical Engineering Company

Prepared for
U. S. Department of Energy
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FOREWORD

The U.S. Department of Energy Field Office, Nevada (DOE/NV) has long been aware of the propensity of tritium to be quite mobile. This tendency of tritium to be very mobile is a commonly known phenomenon. In conjunction with the waste burial operations at the Nevada Test Site, emission of very small percentages of tritium present in waste packages has been observed over the years. For these reasons, DOE/NV invited the University of California to carry out tritium migration studies in conjunction with radioactive waste burial operations at the Area 5, Radioactive Waste Management Site (RWMS). These waste-related tritium migration studies have been underway during the past eight years. Partly as a result of these studies, improvements in waste packaging have been made, also changes in burial procedures such as placing the tritium at deeper depths using the Greater Confinement Disposal (GCD) procedure, have been initiated.

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ABSTRACT

Emanation of tritium from waste containers is a commonly known phenomenon. Release of tritium from buried waste packages was anticipated, therefore a research program was developed to study both the rate of tritium release from buried containers and subsequent migration of tritium through soil. Migration of tritium away from low level radioactive wastes buried in Area 5 of the Nevada Test Site was studied. Four distinct disposal events were investigated. The oldest burial event studied was a 1976 emplacement of 3.5 million curies of tritium in a shallow land burial trench. Tritium transport to the atmosphere by plant transpiration was determined to have risen sharply with the passage of time, and is now occurring at the rate of about 6 curies per year. The tritium being released from this waste has not resulted in elevated tritium levels in the urine of people working directly on the trench cap, so this is scarcely a release rate to cause alarm. Also, air samplers placed around the perimeter of the Area 5 site show no higher tritium levels than the Nevada Test Site in general. In another event, 248 thousand curies of tritium was disposed of in an overpack emplaced 6 meters below the floor of a low-level waste disposal pit. Measurement of the emanation rate of tritium out of 55 gallon drums to the overpack was studied, and an annual doubling of the emanation rate over a seven year period was found. No evidence of significant migration of tritium away from the overpack was found. In a third study, upward tritium migration in the soil was observed in a greater confinement disposal test. Here, the movement was suspected largely to be the result of experimental anomalies and heat generated by other radionuclides present in the waste. Releases of tritium to the atmosphere were found to be insignificant. The fourth event consisted of burial of 2.2 million curies of tritium in a greater confinement disposal operation. No significant migration was found one and one-half years following backfilling of the disposal hole.

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INTRODUCTION

In the ideal case, when radionuclides are disposed of by land burial they are to stay put, *i.e.* not migrate. Most radionuclides are cations and as such they are strongly adsorbed on soil colloids and will not readily migrate, even under the influence of flowing water. Other radionuclides such as ruthenium-106 or technetium-99 may be present in waste as anions and will not be strongly adsorbed on soils by cation exchange processes. These anionic radionuclides will move freely under the influence of flowing water.

Tritium, when present in wastes as the oxide, is water, and will undergo isotopic dilution with any and all water present in the soil. This will include water present in both liquid and gaseous phases. Any movement of soil water, then, either as liquid or vapor, will result in tritium migration away from the buried waste. This is in contrast to the anionic and cationic radionuclides mentioned above which, in order to move, must be transported by liquid water. The inherent ability of tritium oxide to be transported readily in both the liquid phase and the gaseous phase accounts for its high mobility. It is no surprise then, that tritium migration has been found at all commercial Low Level Radioactive Waste (LLRW) disposal sites studied (1).

The Nevada Field Office of the U.S. Department of Energy (DOE/NV) has been quite aware of this mobility of tritium, including the propensity of small percentages of tritium to be released routinely from waste packages. For this reason, DOE/NV invited the University of California to carry out tritium migration studies in conjunction with waste burials at the Area 5 Radioactive Waste Management Site (RWMS). These waste-related tritium migration studies have been under way during the past eight years. The study has confirmed the emanation of tritium from the waste containers and subsequent migration of an extremely small percentage of buried tritium to the atmosphere.

The purpose of this manuscript is to report findings on tritium movement at the defense low-level radioactive waste disposal site in Area 5 of the Nevada Test Site (NTS).

METHODS AND MATERIALS

The tritium migration studies at the Area 5 Radioactive Waste Management Site (RWMS) at NTS have been undertaken as four distinct efforts. The first effort was a study of transport of tritium from buried waste to the atmosphere by plant transpiration. This work has been carried out on Trench T-4 where burial activities were completed in 1976. The second effort is related to tritium emanation from waste containers and migration into surrounding soil. That waste disposal operation took place in 1983 under Pit 1. The third study effort is concerned with tritium migration and atmospheric release from the Greater Confinement Disposal Test (GCDT). The fourth study and the one most recently undertaken was soil migration of tritium from Greater Confinement Disposal (GCD) in Area 5.

In 1976, solid form radioactive waste containing 3.5 million curies of tritium was buried at one location in Trench T4. The waste was delivered to the test site in 55 gallon drums and the drums were placed in overpacks of surplus aircraft jet engine containers prior to burial. The tops of the overpacks are covered with approximately 2.5 m (8 ft) of local soil which serves as the trench cap. Tritium migration studies were initiated on this area in 1983. A plot area 7 m x 14 m centered over the buried containers was established as a vegetative sampling area. This plot area was centered 150 m north of the south concrete trench T4 marker. Initially, the plot area had an Alta Fescue grass cover. The grass cover was followed in succession by a native plant cover of various Atriplex and creosote bushes. Plant transpiration of tritium was measured by foliage sampling, followed by room temperature vacuum distillation of the foliage. The tritium concentration in the distillate was determined by liquid scintillation directly based on U.S. Bureau of Standards tritium standards.

The second effort is related to a tritium waste disposal in 1983. That burial took place under the floor of Pit 1. That effort is pictorially shown and described in Fig. 1. Sixteen 55 gallon barrels containing a total of 248,000 curies of tritium wastes were placed in an overpack consisting of a used engine container. The two halves of the overpack were bolted together so as to leave a 0.6 cm longitudinal gap entirely around the overpack. Soil atmosphere samplers were spatially distributed and the waste emplaced as shown in Fig. 1. The tritium emanation rate from the barrels to the void space in the overpack was determined periodically by pumping air into the bottom of the overpack at 2 liters per minute and pumping air out the top of the overpack at 2 liters per minute. The tritium concentration of the airflow was then measured until the concentration was reasonably constant. At that time pumping was discontinued for several months to a year, when another emanation rate determination was made. The concentration of tritium in the atmosphere of the soil in the near vicinity of waste was determined time to time using the soil atmosphere samplers. An extremely low pumping rate (1 m^3/year) was used to obtain each air sample consisting of approximately 30 liters. Water and tritium oxide were recovered with a freeze trap

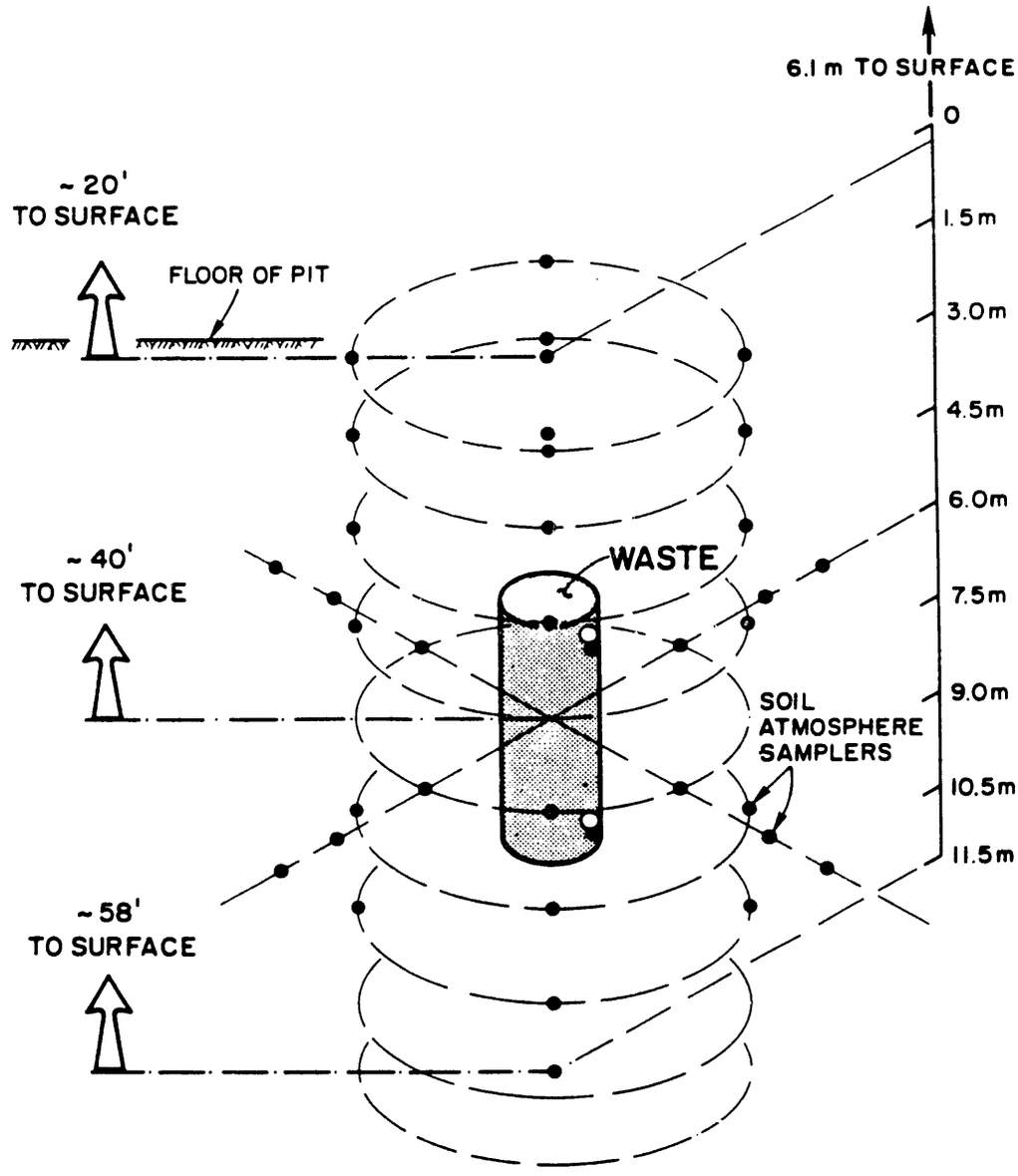

Fig. 1 Emplacement of 248,000 curies of tritium waste under pit floor, March 22, 1983. Sixteen 55 gallon barrels containing tritium wastes were placed in a surplus aircraft engine container depicted as a shaded cylinder. The black dots represent the spatial arrangement of the soil atmosphere samplers which are connected to the surface with 3/16" dia. copper tubing. Periodically, the soil atmosphere samplers were used to obtain ^{3}H concentration in the soil air. Soil air sampling was at the extremely low flow rate of 1 m^3-air/year. Tritium emanation from the barrels (source term) is determined by flowing air into the bottom of the aircraft container and out the top of the container with the ^{3}H concentration in the airstream being measured. Locations of the in-and-out ports in the aircraft container are shown as white circles in the drawing.

and the air volume measured with a piston. As noted earlier, tritium analyses were by liquid scintillation directly based on tritium standards supplied by U.S. Bureau of Standards. No vegetation was present at this location.

The third study on tritium migration was carried out at the Greater Confinement Disposal Test (GCDT) facility. A total of 594,000 curies of tritium were disposed of in this facility in 1984. Here tritium was disposed of at a depth ranging from 20 to 27 meters below grade. Other radionuclides emitting heat were disposed of at lower depths. Complete details of the GCDT facility are given in earlier publications (2, 3, 4). From 1984 to 1987 the GCDT facility was used for *in-situ* gas tracer experiments. Tritium migration studies were begun in 1987. Soil atmosphere tritium sampling was generally similar to that used in Pit 1 except that higher flow rates were necessitated due to water vapor diffusion through the teflon sampling lines. Experimental measurements showed that flow rates of 200 ml/min were necessary to ensure that vapor diffusion would have negligible effects on the measured results. An approximation of the tritium being released from the facility to the atmosphere was made in a fashion generally similar to the emanation rate determination from the barrels to the overpack void described above. In this case, the void was enclosed space at the surface of GCDT with air being pumped into the void at 5 liters per minute and pumped out at 5 liters per minute. The tritium concentration of the outflow air was periodically measured. No vegetation was present at this site, so no plant transpiration data was obtained.

The fourth study of tritium migration at the Area 5 waste management site was in connection with a greater confinement disposal (GCD) of 2.2 million curies of tritium in a 3 meter diameter by 36 meter deep borehole. The waste was emplaced over a three year period, in 1985 through 1987. The top layer of waste was placed 20 meters below grade and the hole then backfilled with soil. Soil atmosphere samples were located in the borehole at various intervals beginning at the bottom of the hole, (the 36 meter depth) while the uppermost samplers were placed 3 meters below the surface. Soil atmosphere sampling and tritium determinations were identical to those described for Pit 1. This borehole has recently been backfilled and no vegetation is present and no transpiration data was obtained.

RESULTS AND DISCUSSION

Trench T4 Studies

The first tritium migration studies of this effort were begun on trench T4 in 1983. Investigation of tritium transport to the atmosphere by plant transpiration was carried out from 1983 through 1990. Data obtained is given in Table 1. This data is presented graphically in Fig. 2. The important finding is that the release of tritium to the atmosphere is not in a steady state condition, but quite to the contrary, it is rising markedly every year. This rapid rise of tritium release is occurring in spite of the 12 year half-life of tritium. Some of the increase possibly can be attributed to growth of the vegetation and deeper penetration of roots with the passage of time. However, we will see in the second effort of this work described below, that a large part of this increase can probably be attributed to increased emanation of tritium from the waste containers. It should be noted that although the transport rate of tritium to the atmosphere is now about six curies per year and increasing, this is still a very minute fraction of the waste buried. At the current release rate, about 3.6 millionths of the amount buried is released to the atmosphere each year. The tritium being released from that waste has not resulted in elevated tritium levels in the urine of people working directly on the trench cap so this is scarcely a release rate to cause alarm. Also, air samplers placed around the perimeter of the Area 5 site show no higher tritium levels than the Nevada Test Site in general. However with the increasing trend, attention should be given to the migration of tritium away from buried wastes.

Table 1. Annual transport of tritium from buried waste to atmosphere, trench T4

Year	Grass*	Shrub*
	mCi/year	
1983	24	--
1984	97	--
1985	230	250
1986	--	992
1987	--	1290
1988	--	3370
1989	--	4038
1990	--	5619

* Tritium transport by plant transpiration. Grass cover was followed in succession by native shrubs.

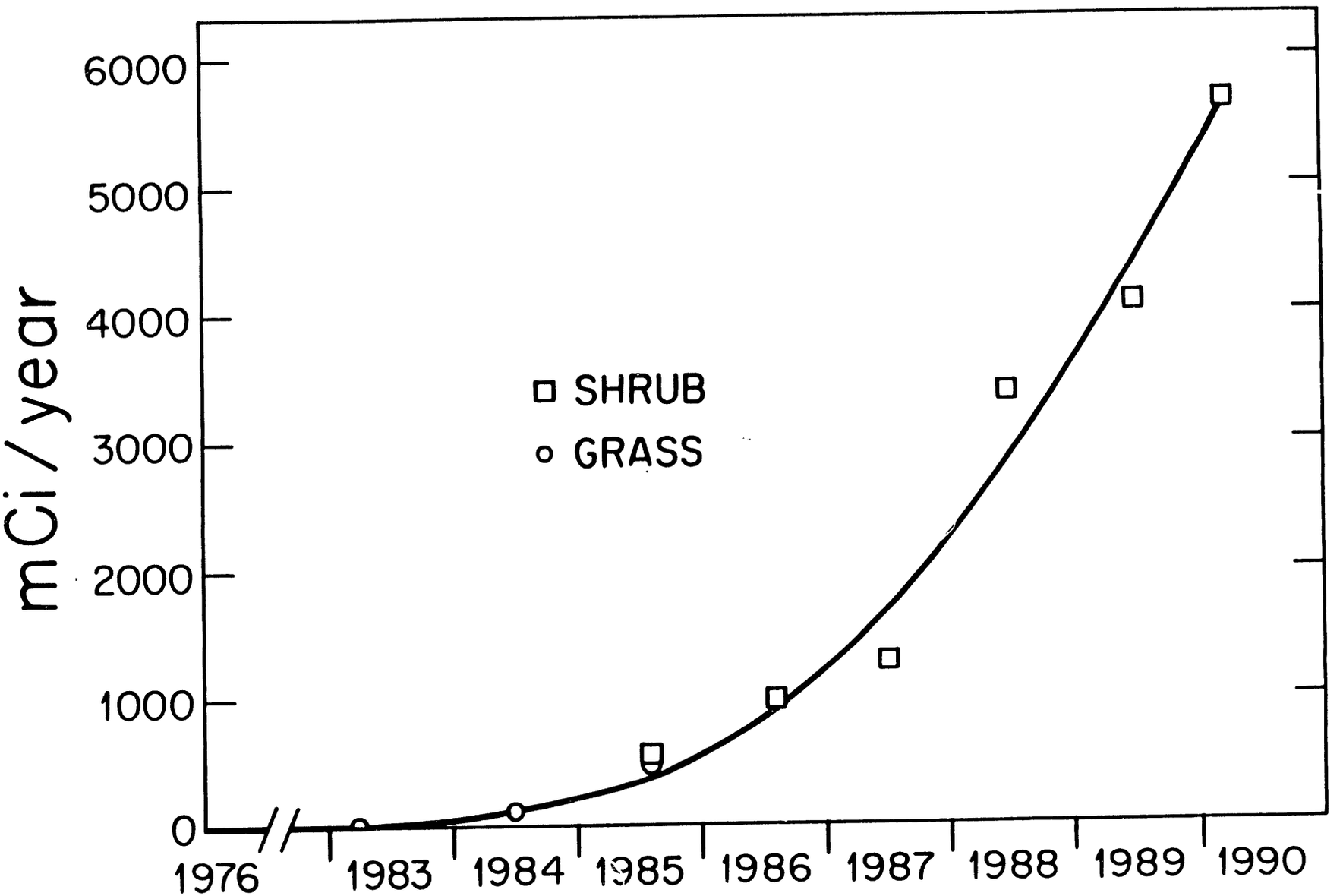

Fig. 2 Transport of tritium to atmosphere by plant transpiration. Initially, a grass cover was utilized on the trench cap plot area. The grass cover was followed in succession by native shrubs. The tritium transpiration in 1985 was the sum of grass plus shrub transpiration.

Pit 1 Studies

The next study carried out was designed to answer two questions. One, what is the release rate of tritium with the passage of time, from the original 55 gallon drums as delivered to the site by the waste generators? The other question, what is the migration rate of the tritium through soil? In this study a 1983 disposal of 0.25 million curies of tritium was carried out by placing 16 drums of tritium in an overpack and burying the overpack 6 meters (20 ft) below the floor of Pit 1 which was being utilized for low-level waste disposal. As described in the methods and materials section, the overpack was deliberately designed to release tritium to the surrounding soil. That is, a longitudinal gap was created in the overpack so that tritium emanating from the drums would be released to the soil. The emanation rate at various measurement times during 1983 through 1990 is given in Table 2. That data is presented in a graphical form in Fig. 3. Here again the movement of tritium from the point of disposal rises rapidly with passage of time. The emanation rate is approximately doubling annually. It also should be noted that this burial is seven years "younger" than the previous burial, *i.e.* the Pit 1 burial is now a 7 year old burial whereas the T4 burial is now a 14 year old burial. At this time about 30 mCi of tritium is being released from the 16 barrels over a one year period. If the trend continues, curie amounts can be expected to be released annually seven years hence. This is probable, based on the past seven years performance and taking into account the data obtained in the T4 study. The second question addressed in this Pit 1 study has not been answered.

Table 2 - Emanation of tritium from 55 gallon drums to void space in overpack. Entire package was emplaced under Pit 1 floor on March 22, 1983. See Fig. 1.

Measurement period	Tritium emanation*
	µCi/day
Oct - Dec 1983	0.62
Jan - Jun 1984	0.65
Nov - Dec 1985	2.2
Jan - Mar 1986	1.4
Apr - Jul 1987	4.7
Jul - Oct 1987	4.4
Oct - Nov 1988	13.3
Dec - Feb 1989	36.4
Jan - Feb 1990	85.5

* Total amount of tritium emanating from sixteen 55 gallon drums.

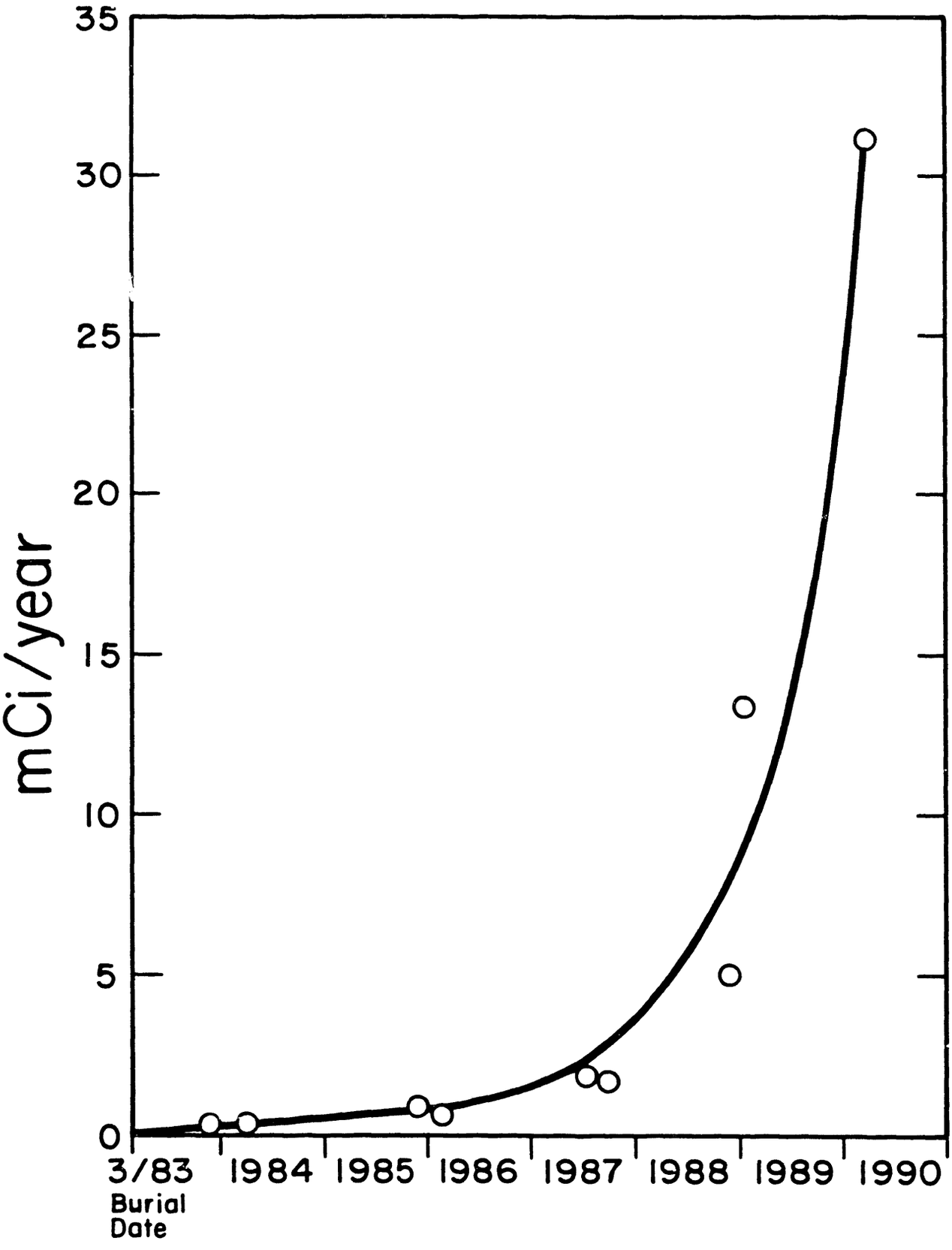

Fig. 3 Emanation of tritium from sixteen 55 gallon drums placed in overpack and buried below floor of Pit 1. See Fig. 1.

The voluminous data obtained from the Pit 1 study is presented in Table 3. A summary of that data is presented graphically in Fig. 4. Inspection of Fig. 4 shows a relatively high concentration of tritium near the level of the floor of Pit 1. This would tend to indicate that the main source of tritium at that location was from the waste disposed of in Pit 1, not from that disposed of in the overpack buried 6 m below the floor of Pit 1. Since the source term is indeterminate, tritium migration rates cannot be calculated with confidence.

GCDT Studies

The third study effort regarding tritium migration at the Area 5 disposal site was at the GCDT facility. Migration of tritium with the passage of time is given in Table 4. This data shows very little lateral migration of tritium but shows very substantial upward migration. Findings from this test should be applied with extreme caution to a routine GCD application since two conditions were present here that will not be present in a routine GCD. One, large amounts of heat are being generated by other radioisotopes present in this test that will (or at least should) be absent from further GCD tritium disposals. The heat drives soil water and tritium oxide in isotopic equilibrium with the water away from the site of disposal. Heat in this test destroyed teflon sampling lines causing possible channels in the soil. Fiberglass insulation surrounding sampling lines may have become damaged, especially the plastic coverings, thus causing a channel for tritium movement. In addition to concentration of tritium in the soil atmosphere, measurements of tritium releases to the atmosphere have been made. This was done by supporting a cover and walls above the soil surface forming an enclosure. Tritium-free air was pumped continuously through the void and the tritium concentration of the exhaust air was measured. The data obtained is given in Table 5. The results show a variable but continuous very small release of tritium to the atmosphere. This release is not significant and unless it were to increase dramatically, is of no practical importance. This release does not, however, necessarily meet the criterion of "as low as reasonably achievable" which probably would have been more nearly met had the experimental anomalies not been present.

GCD Studies

The fourth study and the one most recently undertaken was in connection with an operational GCD tritium disposal. Lessons learned in the earlier 3 types of disposals were taken into account. Improvements in waste packaging have been made since the 1976 burial, and shipments employing the old type of packaging previously used by Mound Laboratories have not been received for a number of years. Even with the improved packaging, some tritium emanation from waste packages was expected, so it was decided to further reduce tritium transport to the atmosphere by providing the longer soil pathway offered by deeper burial using the GCD procedure. Here 2.2 million curies were disposed of in one borehole during the period May 1985 - May 1987. Data obtained one and one-half years after the hole was backfilled show extremely low concentrations of tritium in the soil atmosphere and little migration has occurred. See Table 6. However, based on past experience in cases one and two cited in this report, the waste containers can be expected to degrade thus releasing increasing amounts of tritium to the soil with the passage of time and the migration rate will probably then be important.

Table 3. Spatial distribution of tritium in soil atmosphere in the region of the emplaced tritium waste, Pit 1. See Fig. 1.

Depth (m)	Lateral (m)	^{3}H DPM/L in Soil Atmosphere														
		8-14-84	8-28-84	9-11-84	9-20-84	10-22-84	10-31-84	11-15-84	12-5-84	12-20-84	1-24-84	2-8-85	2-22-85	3-21-85	4-15-85	5-31-85	6-21-85
0.3 N	1.5	–	–	0.6	0.9	NS	0.5	0.5	0.4	0.1	0.3	1.1	3.0	5.7	5.1	7.4	7.1
1.5 N	•	–	–	–	–	–	–	–	–	–	–	–	0.6	NS	4.5	10.2	11.3•
3.0 N	•	–	–	–	–	–	–	–	NS	–	–	–	0.4	1.1	1.8•	6.9	4.5•
4.5 N	•	–	–	–	–	–	–	–	–	–	–	–	0.3	3.2	2.1•	5.8•	0.5•
6.0 N	•	–	–	–	–	–	–	–	–	–	–	–	–	0.3	0.4	1.4•	–
•	3.0	–	–	–	–	–	–	–	–	–	–	–	–	0.1	0.9	2.0	1.1
•	4.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.6	0.3•
7.5 N	1.5	NS	–	–	–	–	–	–	–	–	–	–	–	–	–	0.3	0.4
9.0	•	–	–	–	–	–	–	–	–	–	–	–	–	–	0.1	0.4•	0.2•
0.3 S	•	–	0.8	0.5	0.1	0.3	0.2	0.2	0.1	0.1	0.6	0.3	2.2	12.2	7.1	11.7•	22.8
1.5 S	•	–	–	–	–	–	–	–	–	0.2•	–	–	–	1.6	6.8	23.1•	27.2
3.0 S	•	–	–	–	–	–	–	–	–	–	–	–	–	0.1	1.0	3.3•	1.3•
4.5 S	•	–	–	–	–	–	–	–	–	–	–	–	–	0.5	1.1	2.8	4.6
6.0 S	•	NS	–	–	–	–	–	–	–	–	–	–	–	0.2	0.5	1.4	2.7
•	3.0	–	–	–	–	–	NS	–	–	–	–	–	–	NS	1.2	4.2	NS
•	4.0	–	–	–	–	–	–	–	–	–	–	–	–	–	0.4	1.4	0.9
7.5 S	•	–	–	–	–	–	–	–	–	–	NS	–	–	0.3	–	0.3•	NS
9.0 S	•	–	–	–	–	–	–	–	–	–	–	–	–	0.4	0.5	1.0	0.8
0.3 C	center	–	–	0.1	–	–	–	–	–	–	–	0.2	2.2	6.5	6.6	7.2•	11.8
1.5 C	•	0.2	–	–	1.0†	–	–	–	0.1	0.1	–	–	0.8	3.7	3.2	13.7	10.7
3.0 C	•	–	0.4	0.5	0.4	0.3	0.5	0.3	0.2	0.3	0.1	0.4	NS	4.4	4.1	10.5	19.0
9.0 C	•	–	0.2	0.4	–	–	–	–	–	–	0.1	0.6	0.1	0.6	0.8	1.2	1.4
10.5 C	•	–	–	–	–	–	–	–	–	–	–	–	–	0.2	0.4	1.0	0.8
11.5 C	•	–	–	–	–	–	–	–	–	–	–	–	–	0.2	0.5	1.0	0.8
0.3 E	1.5	–	0.5	0.2	1.0†	0.1	0.1	0.1	0.1	0.1	–	0.3	1.6	2.4•	3.7•	2.5•	6.6•
1.5 E	•	–	–	–	–	–	–	–	–	–	–	–	–	0.5	0.6•	8.5•	7.3•
3.0 E	•	–	–	–	–	–	–	–	–	–	–	–	–	0.2	3.0	5.4	7.8
4.5 E	•	–	–	–	–	–	–	–	–	–	–	–	–	0.2	0.5	NS	1.9
6.0 E	•	–	–	–	–	–	–	–	–	–	–	–	–	0.1	0.1	0.7	0.3
•	3.0	–	–	–	–	–	–	–	–	–	–	–	–	NS	–	0.2	0.1
7.5 E	1.5	–	–	–	–	–	–	–	–	–	–	–	–	–	0.1	0.7	0.6
9.0 E	•	–	–	–	–	–	–	–	–	–	–	–	0.2	–	0.1	0.8	0.3
0.3 W	•	–	17.1†	0.4	–	–	–	–	–	1.5	0.2•	0.3	3.5	4.9	3.7	–	8.0
1.5 W	•	–	–	–	–	–	–	–	0.4	–	–	–	0.4	2.6	2.2	10.8	4.6
3.0 W	•	–	–	–	–	–	–	–	–	–	–	–	–	1.3	4.8	6.0	5.3
4.5 W	•	–	–	–	–	–	–	–	–	–	–	–	–	1.5	2.2	2.4	NS
6.0 W	•	–	–	–	–	–	–	–	–	–	–	–	–	0.7	0.3	0.8	0.6
•	3.0	–	–	–	–	–	–	–	–	–	–	–	–	0.4	0.5	0.7	0.5
•	4.0	–	–	–	–	–	–	–	–	–	–	–	–	0.2	0.3	0.8	0.4
7.5 W	1.5	–	–	–	–	–	–	–	–	–	–	–	–	0.2	0.5	1.1	0.8
9.0 W	•	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Overpack Top		NS	411†	64.2	13.9	79.9•	NS	14.8•	29.5•	NS	113	NS	126	NS	103	68.3	25.1
Overpack Bottom		NS	NS	NS	NS	NS	18.4•	NS	NS	9.1•	NS	21.8	NS	42	21.8	27.9	20.7

† Collected volume of soil atmosphere in less than 2 L.

• sample counted is less that 0.1 g.

NS = no sample.
– = below detection limit.

Table 3 continued. Spatial distribution of tritium in soil atmosphere.

		^{3}H DPM/L in Soil Atmosphere															
Depth (m)	Lateral (m)	7-15-85	8-5-85	8-30-85	10-2-85	12-4-85	1-31-86	3-3-86	3-24-86	4-24-86	5-27-86	6-23-86	7-25-86	8-20-86	9-22-86	11-3-86	12-1-86
0.3 N	1.5	9.3	38.4	35.2	44.8	39.8	140	124	135	121	89.2	86.7	38.4	47.6	38.3	86.7	71.5
1.5 N	•	8.0*	65.4	65.1	98.2	166	95.3	151	94.8	135	97.9	51.8	59.8	58.2	72.9	141	148
3.0 N	•	6.2	13.8	NS	22.4	28.1	23.4	17.5	27.4	30.8	24.7	18.9	19.2	18.5	20.2	27.4	39.8
4.5 N	•	8.0	21.7	16.0	25.2	17.6	42.7	31.5	18.9	28.3	22.5	19.4	19.2	18.2	29.5	30.0	31.7
6.0 N	•	1.9*	5.9	6.0	5.2	12.0	8.7	9.3	6.8	7.5	7.3	7.2	6.8	6.6	7.4	9.0	7.4
•	3.0	1.1	1.5	3.2	3.2	6.4	6.6	5.9	5.2	5.6	5.3	5.4	5.6	NS	5.3	6.5	6.8*
•	4.0	1.0	2.0*	NS	1.3	2.4	4.0	4.2	3.5	5.3	6.3	7.7	5.6	5.6	4.9	6.8	5.9
7.5 N	1.5	1.2	1.5	1.7	1.8	4.9	5.7	4.8	3.7	5.5	5.4	6.8	5.5	5.2	6.0	3.9	6.4*
9.0	•	0.9	1.9	3.2	3.6	6.5	24.8	7.8	5.3	7.5	7.7	8.8	7.5	6.9	6.6	8.4	6.9
0.3 S	•	26.3	32.5	64.3	74.5	188	279	236	272	233	326	248	237	NS	224	294	258
1.5 S	•	NS	129	126	134	154	273	160	79.8	101	74.5	162	51.0	43.4	32.2	30.6	38.4
3.0 S	•	35.2	26.8	36.1	37.4	41.4	71.0	39.3	47.1	43.6	30.1	39.1	19.1	19.2	15.5	49.2	32.2
4.5 S	•	9.0	7.6	6.7	8.1	9.8	14.1	9.7	7.6	10.1	11.8	11.1	9.6	9.2	8.3	11.8	36.2
6.0 S	•	10.2	11.4	10.9	11.6	12.0	27.4	16.5	15.5	22.3	16.2	13.7	11.4	12.0	11.8	17.8	29.1
•	3.0	17.4	17.0	14.3	18.0	42.4	109	46.4	33.7	35.6	33.9	28.3	24.2	25.7	20.3	27.1	19.2
•	4.0	1.9	2.1	6.4	7.9	20.3	40.0	24.1	20.6	25.9	25.8	23.6	20.5	19.4	16.8	31.1	19.7
7.5 S		3.3*	4.0*	13.2	38.2	26.7	43.3	36.5	26.0	36.4	39.9	33.4	31.1	27.2	26.1	30.8	32.3
9.0 S	•	1.3*	1.6	3.4	4.7	8.9	31.2	NS	17.4	20.6	20.4	16.5	14.4	13.4	12.8	15.6	35.0
0.3 C	center	8.5	20.8*	68.2	56.8	279	126	116	183	124	115	98.9	48.7	51.9	51.0	84.3	84.1
1.5 C	•	8.3	12.1	31.8	28.6	35.2	55.6	33.6	77.4	100	86.4	30.6	16.7	17.8	20.0	29.4	19.0
3.0 C	•	18.8	21.5*	44.9	67.2	19.7	140	54.6	70.4	86.3	62.4	39.6	41.4	36.3	36.1	56.6	55.3
9.0 C	•	2.2	2.2*	5.2	8.6	15.0	12.4	10.0	22.1	13.1	15.6	13.8	14.4	14.2	14.5	19.1	21.9
10.5 C	•	1.0	0.6*	2.8	2.8	7.7	3.5	3.3	3.0	3.9	3.9	3.7	3.8	3.6	3.4	5.0	5.8*
11.5 C	•	1.2	1.1*	2.5	2.6	5.2	NS	3.3	2.8	2.9	2.9	2.8	3.0	2.8	3.0	4.3	3.6
0.3 E	1.5	7.0*	12.4*	49.7	99.9	309	170	263	224	281	385	373	434	503	563	928	700
1.5 E	•	8.6	10.2	19.2	30.2	44.7	142	84.8	62.5	71.9	39.9	36.2	26.7	NS	17.8	21.9	28.4
3.0 E	•	19.6	21.7	38.4	31.6	68.6	299	99.3	53.1	80.4	65.4	57.4	50.4	49.0	41.7	52.3	48.7
4.5 E	•	2.9	2.7	5.7	6.7	16.3	50.0	17.5	14.9	15.3	14.7	13.7	12.3	13.7	11.2	12.8	112
6.0 E	•	0.9	1.7	2.6	1.9	8.0	6.7	6.6	6.6	7.2	7.9	6.9	6.2	NS	1.8	0.6	NS
•	3.0	1.9	1.8	3.5	7.2	61.7	37.8	8.7	6.1	7.0	11.8	10.9	11.7	NS	11.4	10.1	13.0
7.5 E	1.5	1.9	2.6	4.6	9.7	16.9	28.2	29.9	25.2	26.9	23.0	17.2	15.7	13.4	13.3	14.5	14.1
9.0 E	•	0.8	1.1	1.4	2.0	3.0	4.4	2.6	3.4	3.9	4.2	4.3	4.1	3.7	4.0	7.9	4.6
0.3 W	•	12.8	18.1	34.4	59.4	103	81.1	246	117	153	167	97.4	64.2	87.0	78.2	106	115
1.5 W	•	6.3	10.1	22.6	23.2	74.5	63.7	76	70.2	73.6	187	71.2	44.1	NS	23.3	31.8	31.0
3.0 W	•	4.6	5.2	9.5	13.1	10.7	17.3	12.0	17.3	26.5	11.3	10.5	7.7	7.3	7.1	6.2	19.9
4.5 W	•	4.2	3.5	6.8	10.1	12.0	13.1	9.5	7.2	8.0	6.5	8.7	8.1	8.5	8.0	9.5	18.8
6.0 W	•	2.0	1.6	3.3	4.4	8.4	5.4	5.0	4.0	4.8	4.3	4.2	4.2	4.3	4.1	4.6	7.7
•	3.0	1.0	0.9	3.1	3.7	6.2	10.5	5.9	4.7	5.7	4.8	4.6	4.1	4.4	4.6	5.6	15.1
•	4.0	0.8	1.4	1.3	2.2	4.0	4.4	4.6	3.1	3.2	2.8	3.3	2.7	2.9	3.6	5.0	NS
7.5 W	1.5	0.9	1.7	1.9	2.5	7.2	5.2	3.9	4.2	4.0	5.0	4.9	5.0	5.4	3.8	7.5	6.6
9.0 W	•	0.7	0.8	1.1	1.1	1.7	4.8	2.4	2.0	2.6	2.5	1.2	2.2	NS	1.9	3.1	3.4
Overpack Top		112	143	212	308	513	400	397	441	526	561	516	520	451	671	515	923
Overpack Bottom		29.2	35.4	91.3	93.4	152	NS	141	137	141	151	167	163	151	143	208	129

† Collected volume of soil atmosphere in less than 2 L.

* sample counted is less that 0.1 g.

NS = no sample.

– = below detection limit.

Table 3 continued. Spatial distribution of tritium in soil atmosphere.

Depth (m)	Lateral (m)	^{3}H DPM/L in Soil Atmosphere 1-27-87	2-25-87	3-18-87	5-28-87	7-17-87	9-29-87	12-3-87	3-7-88	5-16-88	7-20-88	9-15-88	3-8-89	11-8-89
0.3 N	1.5	129	193	219	136	276	226	405	197	374	1337	579	0 8	NS
1.5 N	*	246	264	42.8	817	92.2	48.8	37.5	49.0	111	42.6	37 4	NS	26 2
3.0 N	*	96	146	28.6	38.3	27.5	26.5	27.3	49.7	80.7	44.2	23.1	20 9	NS
4.5 N	*	47.8	80.9	30.2	48.1	44.8	44.9	35.6	50.4	45.3	38.6	39.6	NS	26.9
6.0 N	*	21.6	43.1	9.6	12.0	71.4	11.3	13.9	15.7	19.2	12.4	11.7	9.0	13 4
*	3.0	18.1	27.4	9.4	18.1	13.8	12.8	8.9	19.2	28.2	14.1	10.4	11.2	7.4
*	4.0	35.8	54.0	6 8	13.4	115	12.1	8.0	9.9	18.9	6.5	10.4	1.5	3.4
7.5 N	1.5	11.8	37.0	6.8	9.2	1191	12.0	76.9	12.1	10.2	7.7	7.1	12.2	14.7
9.0	*	31.0	62.0	10.3	17.6	16.9	12.7	19.6	10.3	10.1	10.6	9.5	7.3	7.2
0.3 S	*	390	512	416	493	590	514	353	390	743	1036	651	445	NS
1.5 S	*	68.5	101	49.5	1086	87.8	57.6	242	44.4	77.7	75.5	45.6	41.0	NS
3.0 S	*	69.5	105	16.6	106	104	32.5	31.5	28.4	32.6	44.1	26.7	32.7	17.7
4.5 S	*	74.8	33.0	4.6	17.4	63.2	14.8	40.0	46.9	59.9	27.4	10.6	11.4	9 4
6.0 S	*	79.6	57.5	13.2	1630	21.8	17.2	41.0	54.9	22.4	16.8	14 7	17 0	16 8
*	3.0	81.1	82.3	24.1	53.5	42.8	31.5	31.8	29.5	30.2	31.2	23.9	20.6	13.2
*	4.0	44.7	30.3	13.2	31.6	35.0	24.2	62.8	18.9	18.4	20.4	15.4	16.2	8.8
7.5 S	*	118	175	17.9	56.4	30.0	27.8	28.6	35.2	29.6	22.5	20.4	30.2	13.9
9.0 S	*	70.4	108	14.2	44.0	124	21.9	22.1	16.9	19.7	19.3	17.1	20.9	16.3
0.3 C	center	109	416	231	359	461	373	362	308	1196	1179	737	394	1145
1.5 C	*	47.6	121	99.8	392	48.3	42.4	36.2	63.5	86.2	80.3	34.4	28.0	40.2
3.0 C	*	79.9	240	69.5	65.0	75.0	76.7	82.5	121	216	149	102	77.8	230
9.0 C	*	26.1	25.4	23.0	37.6	33.8	31.4	39.1	NS	55.2	54.6	46.2	59.8	140
10.5 C	*	20 4	20.5	5.8	11.9	18.4	7.5	85.2	5.4	7.3	7.8	40.4	105	6.5
11.5 C	*	12.5	7.1	4.0	25.2	22.0	5.7	6.6	8.7	7.0	13.7	7.8	6.3	NS
0.3 E	1.5	864	3584	1717	2078	3405	3392	3354	7394	11640	15390	9713	5083	11900
1.5 E	*	110	277	100	120	148	34.1	40.2	59.3	63.8	70.5	26.6	26.5	53.5
3.0 E	*	119	214	46.0	80.9	323	52.6	89.6	104	106	37.0	34 4	36.8	21.0
4.5 E	*	32.6	46.1	36.0	36.0	19.9	15.5	17.4	25.2	62.8	20.7	19.5	8.1	12.5
6.0 E	*	18.0	54.2	13.7	10.0	10.3	11.1	64.6	12.5	16.1	34.2	NS	15.9	9.5
*	3.0	22.2	14.7	6.8	28.2	12.9	15.4	19.6	13.0	22.2	12.0	NS	12.3	7.2
7.5 E	1.5	13.5	14.8	10.8	1514	16.7	15.0	18.2	16.1	NS	13.9	12.2	13.2	13.8
9.0 E	*	7.5	7.1	8.4	6.9	7.8	5.4	7.2	7.0	6.3	5.8	3.7	7.1	7.4
0.3 W	*	233	255	210	270	449	280	303	321	236	418	NS	110	174
1.5 W	*	89.7	158	62.9	139	68.6	31.0	51.6	39.3	58.8	46.4	127	34.5	18.7
3.0 W	*	51.1	57.4	37.0	116	28.9	21.0	11.8	25.5	33.3	31.6	16.9	9.7	7.0
4.5 W	*	56.8	14.9	11.7	18.9	16.9	16.3	18.6	26.8	66.9	19.3	14.9	32.5	23.1
6.0 W	*	26.0	16.3	5.3	7.5	6.7	11.1	11.0	13.5	15.2	11.3	6.5	9.7	8 0
*	3.0	31.2	73.6	8.0	26.6	23.0	8.5	16.8	20.2	12.0	7.1	6.4	8.9	6.0
*	4.0	11.8	5.6	4.7	195	7.5	16.4	6.7	7.5	8.9	6.9	3.9	4.8	5 1
7.5 W	1.5	8.9	7.3	7.1	12.1	17.0	82.7	76.6	641	13.3	13.7	10.1	14.2	52.6
9.0 W	*	5.2	3.6	3.3	8.4	14.9	4.1	335	3.6	6.9	7.6	10.8	227	7.7
Overpack Top		1942	NS	1522	1366	1161	1087	2072	4806	3152	2188	1919	3115	10890
Overpack Bottom		287	259	251	361	321	386	NS	586	604	NS	514	2535	NS

† Collected volume of soil atmosphere in less than 2 L

* sample counted is less that 0.1 g.

NS = no sample.

– = below detection limit.

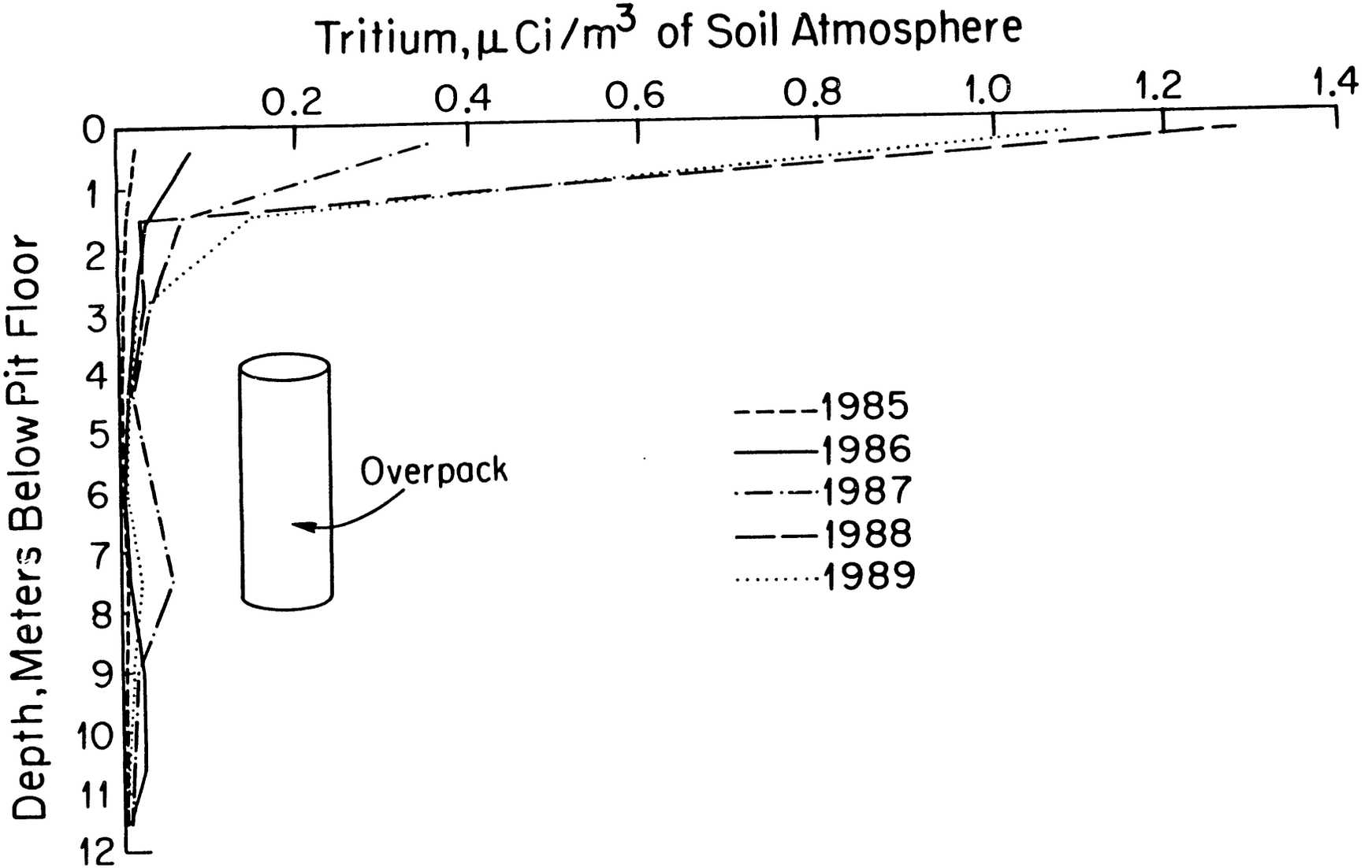

Fig. 4 Spatial distribution of tritium in the soil atmosphere under the floor of Pit 1.

Table 4. Spatial distributions of tritium oxide concentration in soil atmosphere, GCDT. (microcuries/cubic meter of soil atmosphere)

SAMPLER DEPTH (m)	RADIAL DIST. (cm)	DATE 5/14/87	6/17/87	11/30/87	4/11/88	9/15/88
		$\mu Ci/m^3$				
3	160	44.0	57.0	32.0	66.0	206
	168	29.0	24.0	5.70	14.0	15
	282	0.39	0.285	0.113	0.10	.22
	447	0.06	0.443	0.032	0.08	--
	625	0.03	0.042	--	0.06	.09
	640	0.004	0.009	0.003	--	.03
9	160	120.0	217.0	75.0	216.0	400
	168	220.0	208.0	35.0	80.0	88
	279	0.29	0.401	0.695	0.50	--
	447	0.25	0.637	0.252	0.27	.59
	457	0.03	0.028	0.009	0.01	.03
	640	0.03	0.028	0.025	0.04	.07
15	168	680.0	648.0	63.0	242.0	269
	279	19.0	26.3	2.05	23.0	16
	282	0.43	0.999	0.464	0.90	.93
	447	0.10	0.479	0.328	0.65	.99
	457	0.06	0.044	0.020	0.06	.08
	625	0.09	0.205	0.147	0.21	.31
	640	0.03	0.25	0.028	0.04	.08
22	168	--	3810.0	160.0	411.0	693
	279	40.0	23.2	16.1	7.0	12
	282	18.0	14.4	1.03	1.5	2.7
	447	1.3	1.32	0.357	0.69	1.2
	640	0.04	0.063	0.022	0.04	.09
28	160	1370.0	2330.0	362.0	678.0	1090
	168	7200.0	7990.0	1036.0	2350.0	1380
	279	30.0	363.0	59.3	61.0	104
	282	11.0	36.3	1.94	2.1	20
	447	0.60	1.01	0.334	0.420	1.0
31	279	55.0	44.5	20.0	39.0	58
	282	2.0	2.07	0.464	1.3	1.9
	447	0.57	0.541	0.281	0.6	.96
	625	0.43	0.340	--	--	--
37	168	7900.0	7940.0	1280.0	2460.0	1280
	447	0.96	0.650	0.334	0.43	.81
	457	0.12	0.282	0.023	0.05	.13

Table 5. Tritium transport to the atmosphere from GCDT central borehole.

Date	µCi/day	Date	µCi/day
1-29-88	2.34	7-26-88	22.18
2-02-88	2.66	8-02-88	51.98
2-03-88	1.67	8-11-88	41.11
2-10-88	3.22	8-18-88	29.09
2-11-88	3.12	8-24-88	28.44
2-12-88	3.29	8-25-88	28.66
2-23-88	5.36	9-01-88	28.80
2-24-88	5.20	9-19-88	18.65
2-25-88	4.18	9-27-88	22.39
3-03-88	6.05	10-05-88	49.25
3-09-88	3.90	10-17-88	18.50
3-15-88	7.20	10-26-88	36.79
3-16-88	4.90	11-16-88	15.26
3-17-88	4.74	11-21-88	11.30
3-18-88	4.62	12-01-88	10.22
3-23-88	9.43	12-07-88	11.81
3-24-88	9.29	12-14-88	22.54
3-31-88	11.38	1-10-89	4.91
4-01-88	9.22	1-20-89	8.01
4-05-88	4.70	1-26-89	8.08
4-13-88	16.70	2-01-89	9.07
4-14-88	13.82	2-16-89	10.09
4-20-88	16.27	2-24-89	14.16
5-05-88	23.76	10-19-89	21.9
5-13-88	22.46	10-24-89	3.7
5-16-88	37.44	10-27-89	13.9
5-23-88	24.98	11-02-89	11.1
6-08-88	21.10	11-09-89	12.4
6-13-88	28.37	11-30-89	8.7
6-15-88	27.94	12-07-89	8.4
6-20-88	27.22	1-04-90	6.3
7-07-88	32.26	1-17-90	11.4
7-14-88	25.99	1-23-90	6.8
7-19-88	24.55	2-14-90	25.6
7-21-88	20.30	2-22-90	9.6

Table 6. Tritium concentration in soil atmosphere in GCD. Borehole backfill completed on June 19, 1987, and tritium sampling carried out on December 13, 1989.

Sampler Depth		Tritium Concentration in Soil Atmosphere
m	ft	$\mu Ci/m^3$
3	10	0.001
6	20	0.004
9	30	0.001
12	40	0.004
15	50	0.001
20	65	0.010
26	85	0.220
36	119	0.070

CONCLUSIONS AND RECOMMENDATIONS

Data obtained in the Pit 1 study show that tritium emanation from those buried waste containers has been increasing rather rapidly with the passage of time. It appears that the rate of increase of release may double annually for a significant period of time. The initial emanation rate is extremely low, so that even with large annual percentage increases, the total releases so far have been small. The increasing release rates from the containers do point up the necessity of having accurate site-specific soil tritium migration rate data available. Clearly the soil must ultimately be charged as the primary containment media. Accurate site-specific migration rate data would enable prediction of tritium release rates to the atmosphere or migration downwards toward the water table. It should be noted that all tritium studies to date at Area 5 have been in conjunction with actual radionuclide disposal operations and therefore the source term of the tritium available for migration is always unknown. A specific experiment, with a completely soluble tritium oxide source should be conducted to obtain accurate site-specific tritium migration rates for the Area 5 disposal site.

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