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STATUS REPORT ON EVALUATION OF
SOLID WASTE DISPOSAL AT ORNL: II

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OAK RIDGE NATIONAL LABORATORY

operated by

UNION CARBIDE CORPORATION

for the

U.S. ATOMIC ENERGY COMMISSION

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HEALTH PHYSICS DIVISION

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SUMMARY

Burial Ground 4 was opened in February 1951 and closed to routine burial operations in July 1959. The average rate of burial during this period was about 2 1/2 acres per year. Approximately 50% of the buried waste at the site originated at ORNL, while the remainder was contributed by more than fifty off-site agencies.

The site is underlain by the Conasauga shale of Cambrian age. At the burial ground the formation consists mostly of maroon and gray shales interbedded with a few thin limestone lenses. Water-level measurements indicate that the buried waste is in contact with ground water during most periods of the year. Activity was detected in water samples from a number of wells located in areas of low topography where ground water contact with the waste is greatest. Radionuclides were also found in seeps and streams within the area. Identifiable contaminants include Ru^{106} , Co^{60} , Cs^{137} , Sr^{90} , Zr^{95} - Nb^{95} , Pu^{239-40} , Po^{210} , and the rare earths. No significant activity from the burial ground is being contributed to nearby White Oak Creek.

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INTRODUCTION

The first status report¹ on solid-waste disposal at the Oak Ridge National Laboratory (ORNL) discussed the criteria employed in selecting a site, the findings of site evaluation, the design and preliminary findings of new trench construction, and the conclusions relative to expected improvements in a new burial ground. The purpose of this study was to define more specifically the geological and hydrological conditions that exist in Burial Ground 4, now abandoned, and to determine the movement of radionuclides in the area and the amount of activity contributed by the burial ground to nearby White Oak Creek.

LOCATION AND HISTORY OF OPERATIONS

Burial Ground 4 is situated in Melton Valley, within the White Oak Creek drainage basin, and is located 1/2 mile southwest of the ORNL plant site (see Fig. 1). The area was opened in February 1951 and closed to routine burial operations in July 1959. It encompasses an area of about 23 acres, one acre of which remains available for burial. Thus, the burial rate during its 8.5 years of operation was approximately 2.5 acres per year. In general, the burial ground was filled from the northeast to the southwest. The site is currently used as a stand-by burial ground. In addition, a trench for burning noncontaminated material is operated within the area. Much of the site, especially the northeastern section, has been covered with rock and dirt from building excavations at ORNL. In some places as much as 20 ft of this material overlies the buried waste.

① PROCESS WASTE TREATMENT PLANT

②A BURIAL GROUND NO. 1

②B BURIAL GROUND NO. 2

②C BURIAL GROUND NO. 3

②D BURIAL GROUND NO. 4

②E BURIAL GROUND NO. 5

③ SEWAGE TREATMENT PLANT EFFLUENT

④ LAUNDRY EFFLUENT

⑤ WASTE PITS

⑥ BED OF WHITE OAK CREEK IMPOUNDMENT

⑦ TEMPORARY MONITORING STATION 1

⑧ TEMPORARY MONITORING STATION 2

Fig. 1. Locality Map.

The routine burial procedure consisted of excavating trenches in the weathered shale, dumping the contaminated waste into the excavation, and then covering with the original soil. In the case of trenches known to contain alpha-contaminated wastes, approximately 18 in. of concrete was poured over the filled hole. A map of the burial ground showing general trench alignment, type of cover (shale or concrete), the high-level waste burial areas, and the burning pit for noncontaminated material is shown in Fig. 2.

Auger holes, 1 ft to 2 ft in diameter and approximately 15 ft deep, were used to dispose of small packages of higher-level waste and for temporary storage of recoverable materials contaminated with fission products of short half life. About fifty auger holes are located in the northern part of the burial ground along Lagoon Road. In addition, some special high-level waste has been buried in individual stainless steel containers.

The size and shape of the trenches vary greatly. They range from 50 ft to 400 ft in length, 8 ft to 30 ft in width, and 8 ft to 14 ft in depth. Trench alignment is not confined to any one direction, but varies throughout the burial ground. Normally, the trenches were dug with a back-hoe; but in cases where an unusually large trench was needed for bulky items, bulldozers and dip-buckets were used. Burial was limited to higher elevations within the burial ground during the wet periods, while the low topography was utilized during the dry summer months.

A wide variety of contaminated waste has been disposed of at Burial Ground 4. Included are such things as absorbent paper, all types of glassware, scrap metal, dirt, various filters, lumber, irradiated piston rings, oils, powders, wire, depleted uranium, and animal carcasses used for biological experiments. A few large pieces of equipment and a small metal building that could not be economically decontaminated were buried at the site. Some waste

Fig. 2. Trench Alignment and Type Cover at Burial Ground 4.

material was buried in metal, wood, plastic, fiber, and concrete containers, and some was simply dumped into the trenches. In many cases the waste was packed into the trenches by back-hoe and bulldozer, causing most containers to rupture.

Records of the exact amount of waste disposed of at Burial Ground 4 prior to 1957 were destroyed by fire. The volume buried during 1957 and 1958 was approximately 255,000 ft³ and 336,000 ft³, respectively. During these years ORNL produced about 50% of the waste, while other Oak Ridge installations and off-site establishments contributed the remainder. Argonne, Knolls, and Mound Laboratories, and the General Electric Company of Evendale, Ohio, were the principal off-site shippers, but more than fifty agencies used the facility. A summary of the waste disposed for 1957 and 1958 is shown in Table 1.

Little information is available as to the types, concentrations, and quantities of radionuclides disposed of at the site. The curie content of off-site wastes was frequently incomplete. In many instances, the waste was described as having less than a certain quantity of radioactivity, the principal concern being the hazard associated with handling such material due to external radiation. In all instances, information is provided on external radiation associated with each shipment. The problem of adequately describing the contents of the material stems from the heterogeneity of the waste and lack of suitable techniques for sampling. The problem of obtaining representative samples of solid waste for analysis is recognized by the American Standards Association, and a working group of Subcommittee N5.2, Radioactive Waste Disposal, is currently reviewing the problem.

Table 1. Solid-Waste Burials for 1957 and 1958

Agency	1957		1958	
	Volume (ft ³ x 10 ³)	Percentage	Volume (ft ³ x 10 ³)	Percentage
ORNL	142	55.7	158	47.0
Y-12	10	3.9	15	4.4
U.T. Agricultural Experimental Station	4	1.6	4	1.3
ORINS	1	0.4	1	0.3
Oak Ridge Processing Co.	6	2.3	16	4.8
Knoxville Iron Co.	4	1.6	11	3.2
K-25	4	1.6		
Off-Site Shippers				
KAPL	25	9.8	52	15.5
ANL	29	11.4	34	10.1
GE	7	2.7	19	5.6
Mound Laboratory	14	5.5	11	3.3
Radiological Service Co.	4	1.6	4	1.2
BMI			4	1.2
Others	5	1.9	7	2.1
Totals	255	100	336	100

GEOLOGY

Melton Valley is underlain by the Conasauga shale of Cambrian age. Haw Ridge, capped by the resistant Rome formation, bounds the valley on the northwest; and Melton Ridge, underlain by cherty beds of the basal Knox group, bounds it on the southeast. The Conasauga shale in Melton Valley is about 1500 ft thick. The most common angle of dip is 30° to 40° to the southeast. However, due to the incompetent nature of the formation, considerable variations in dip occur. The basal part of the Conasauga consists mostly of red shale. This unit grades upward into gray calcareous shale containing thin lenticular beds of limestone. The amount of limestone increases toward the southeast and is predominant in the uppermost portion of the formation. Silty beds occur throughout the formation, but are most numerous in the lower half. These resistant siltstones account for the line of low hills, or knolls, which rise above the valley floor along the northwest side of the valley.^{2,3}

Burial Ground 4 is situated just northwest of a low hill underlain by siltstone in the lower part of the Conasauga where a transition zone exists between the basal red shales and the overlying gray shales and interbedded lenticular limestones. The formation here consists mostly of dark, maroon-to-brown, noncalcareous shales, interbedded with gray, slightly calcareous shales, and thin, gray-blue, silty limestones. A few discontinuous, relatively pure, thin limestone lenses are present, along with an occasional fine-grained, green, siltstone bed. Red and brown shales predominate in the northwest part of the area; but in the southeast portion, gray shales and interbedded silty limestones are most prevalent. The shales usually weather to a dull olive, yellow,

or brown color; and the silty limestones weather to resistant siltstone lenses. The weathered siltstones and the shales have well-developed joints that are open near the surface. Joint surfaces are frequently stained reddish brown to black. In the higher elevations of the burial ground, weathered material extends down 15 ft to 16 ft; whereas in the lower elevations, fresh rock is encountered within 4 ft to 5 ft of the surface. A few feet of yellow-to-red, clayey soil was observed over some parts of the area, but it did not persist vertically or laterally.

Dip measurements made in and around the burial ground range from vertical to 27° southeast. Strike measurements varied from N. 85° E. to N. 15° E. The wide range in dip and strike indicates that many small structures are present within the site.

HYDROLOGY

All drainage from Burial Ground 4 is into White Oak Creek above White Oak Dam. Most of the surface and ground water from the site flows to the northeast and enters the creek above the gaging station. However, because of the low topographic divide that exists along the southwest boundary of the site, there is some drainage southwestward. White Oak Creek discharges into the Clinch River about 2 miles below the burial ground.

In order to define more fully the geologic and hydrologic conditions that exist at the site, a series of twenty-one auger holes, ranging in depth from 5 ft to 20 ft, were dug. Water-level measurements in these wells, taken about once each week during the period, August 17, 1959, to April 29, 1960, indicate that the water table fluctuates between 2 ft to 3 ft below the surface in low areas of the burial ground and 10 ft to 15 ft beneath higher elevations. Hydrographs for wells 182 and 185, the former located in high topography and the

latter in a low elevation, illustrate these fluctuations (Fig. 3). Thus, waste buried in the low areas is in contact with ground water at all times, but in the higher areas ground water intersects the material only during the wet season. Typical wet weather conditions are illustrated in Fig. 4, a depth-to-water map for December 24, 1959. It is quite probable that the water level will rise even nearer to the surface during times of unusually heavy rainfall.

Water-table contour maps of the area show that the water table is essentially a subdued replica of the topography (Fig. 5). From previous work it is known that the rate of ground-water movement in the Conasauga shale is greatest along the strike of the formation.^{3,4} However, as a result of trench excavation, the regular pattern of water movement has probably been disrupted in the uppermost part of the weathered shale. Thus, the principal movement is more likely in directions normal to the contour lines in the disturbed part of the shale and along strike at greater depths.

Although the rate of ground-water flow at the burial site is not known precisely, the slow recovery of water levels in the auger wells after pumping suggest that the movement of water in the upper portion of the shale is relatively slow. Due to the low permeability of the formation and the shallow depth of the holes, the wells were pumped dry in a few minutes. Thus, information only as to the relative measurements of the rates of water movement were determined by these pumping tests. Similar water level recovery results have been obtained from pumping tests in auger holes at Burial Ground 5, which is located in the same geologic formation about 1/2 mile to the northeast. This suggests that the rate-of-water movement through the Conasauga shale does not vary greatly between the two sites. The rate-of-waste movement through the weathered shale at the ORNL waste-seepage pit area, located approximately

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Fig. 3. Comparison of Hydrographs for Two Wells at Different Elevations.

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Fig. 4. Depth to H₂O Contours at Burial Ground 4, December 24, 1959.

Fig. 5. Water-Table Contours at Burial Ground 4, December 24, 1959.

1/2 mile southwest of the burial ground in the Conasauga shale formation, varies from 2 ft to 30 ft per day along strike.⁴ Although the rate of flow of waste is somewhat slower than ground water and the presence of large amounts of liquids cause an increase in the flow of water away from the pits,³ the rate of ground-water movement at Burial Ground 4 is not believed to be greatly dissimilar.

FINDINGS WITH RESPECT TO UNDERGROUND AND SURFACE CONTAMINATION

To define and determine the extent of surface and underground contamination in the burial ground, water samples were taken and analyzed from wells and seeps in the area and from the intermittent stream flowing through the site. Temporary monitoring stations were installed along White Oak Creek to determine the amount of activity leaving the site.

Wells

Activity has been detected in eight of the sixteen wells located within the burial ground (see Fig. 6). Beta-gamma contamination was observed in all eight wells, but only No. 185 is believed to be contaminated by alpha activity. With the exception of well 182, all contaminated wells are located in areas where the water table is relatively near the surface (see Fig. 4). By radio-logging the wells with a scintillation probe,^a it was found that the activity in wells located in low topography was most concentrated within a few feet of the ground surface. In the case of well 182, the maximum intensity was observed at a depth of about 12 ft. In general, one would expect the activity to enter the wells near ground-water contact in the weathered portion of the shale.

^aDeveloped by U. S. Department of Interior, Geological Survey, Federal Center, Denver, Colorado. Contains a 1-1/2-in. diameter by 1-1/2-in.-thick sodium iodide crystal and phototube in a brass housing.

Fig. 6. Wells and Seeps Showing Activity.

Water samples were taken about once each week from all wells in and around the burial ground during the period, August 17, 1959, to January 22, 1960, and analyzed for gross-beta and gross-alpha activity. In the contaminated wells, the average gross-beta activity ranged from 1.3 counts $\text{min}^{-1} \text{ml}^{-1}$ (well 195) to 12 counts $\text{min}^{-1} \text{ml}^{-1}$ (well 196). The average gross-alpha activity in well 185 was 1.0 counts $\text{min}^{-1} \text{ml}^{-1}$. Composite samples from wells 182, 191, 194, 196, and 197 were analyzed for specific radionuclides and chemical ions. Identifiable contaminants include Sr^{90} , Ru^{106} , and the rare earths. A summary of the activity observed in the wells is shown in Table 2.

In Table 3 the chemical analyses of composite well samples, as well as seep and stream samples, are compared to the analyses of uncontaminated well samples taken at Burial Ground 5 prior to its use. The relatively high concentrations of Na^+ , Cl^- , NO_3^- , and SO_4^{--} ions found in the contaminated water samples show that chemical ions are also being leached from the buried material.

The amount of activity observed in the wells varied with the sampling date. By comparing gross counts with water-level elevations in the wells at the time the samples were taken, some relations are noted. In the case of wells 194 and 185, the rise in water-table elevation during the wet season is accompanied by an increase in gross counts (see Figs. 7 and 8). This increase is particularly noticeable, since prior to the increase in water levels the wells contained only trace amounts of activity. For wells 182, 191, 196, and 197, the trend seems to be toward a smaller concentration of activity as the water table rises (see Figs. 9-12). The activity in wells 186 and 195 was so low and erratic that no relation with ground-water-level elevation was apparent.

Although there seems to be a direct relationship between activity observed in at least some of the contaminated wells and the ground-water-level elevation observed in the wells, the reasons for this are not clear. Perhaps

Table 2. Summary of Activity in Wells

Well Number	Number of Samples Taken 8/17/59 to 1/22/60	Gross Activity ^a β counts/min/ml, except 185 α counts/min/ml			Radionuclides In Composite Sample		
					Sr ⁹⁰	TRE ^b	Ru ¹⁰⁶
		Max	Min	Mean	(dis/min/ml)		
182	21	12	3.4	8	25	39	4
185 ^c	21	3.8	0	1.0			
186 ^c	21	20	0	2.4			
191	21	16	4.2	7	22	33	3
194	20	14	0	5.8	32	48	d
195 ^c	19	8	0	1.3			
196	20	31	4.4	12	56	83	< 1
197	21	12	0	4.2	24	36	d

^aGross beta counted at approximately 8% geometry. Gross alpha counted at approximately 47% geometry.

^bTotal rare earths counted at 22.3% geometry.

^cNot analyzed for specific nuclides.

^dNone detected.

Table 3. Chemical Analyses of Water from Auger Wells, Seep, and Stream in Burial Ground 4 and Noncontaminated Auger Wells in Burial Ground 5

	Ca ⁺⁺	Na ⁺	NO ₃ ⁻	Cl ⁻	SO ₄ ⁻⁻	Total Hardness as CaCO ₃
(parts per million)						
Contaminated Wells in Burial Ground 4						
Wells						
182	50	92	24	74	800	749
191	30	34	20	32	71	211
194	394	58	88	674	780	1420
196	40	56	19	59	143	295
197	67	56	29	87	163	270
Seep 2	26	72	32	78	78	194
Stream	25	41	35	39	51	147
Noncontaminated Wells in Burial Ground 5 ^a						
Composite Sample of 4 Wells	68	2.1	1.2	1.3	8.7	193

^aSamples at Burial Ground 5 taken prior to burial.

Fig. 7. Comparison of Gross-Beta Activity and Water-Level Elevations in Well 194.

Fig. 8. Comparison of Gross-Alpha Activity and Water-Level Elevations in Well 185.

Fig. 9. Comparison of Gross-Beta Activity and Water-Level Elevations in Well 182.

Fig. 10. Comparison of Gross-Beta Activity and Water-Level Elevations in Well 191.

Fig. 11. Comparison of Gross-Beta Activity and Water-Level Elevations in Well 196.

Fig. 12. Comparison of Gross-Beta Activity and Water-Level Elevations in Well 197.

the additional amount of water accompanying a rise in the ground-water level is simply diluting the waste solution, or the rise in water table may cause additional leaching of the waste, resulting in higher concentrations of radionuclides. Other conditions also complicate the interpretation of these data. The heterogeneous nature of the waste, the lack of detailed burial information, and the lack of specific information concerning the waste, such as the type, concentration, chemical state, and amount of activity, prevent a more complete understanding of these relations.

Liquid samples were obtained by lowering a container into the well and allowing it to fill as it settled to the bottom. Samples obtained in this manner may not be representative of liquid in and around the vicinity of the well. To determine the effectiveness of the type sampling and to help define the rate of H_2O movement in the weathered shale, most of the wells showing activity and some of those not contaminated were pumped dry and allowed to recover. Water samples taken in each well, before, during, and after the pumping, were analyzed for gross-beta and alpha activity. Results showed no appreciable change in the concentration of activity in the wells. Thus, it is believed that representative samples of the ground water in and around the shallow auger holes was obtained by sampling in the fashion described.

Seeps and Streams

Radionuclides have been detected in several seeps that occur throughout the area, especially during the wet season. Many of the seeps seem to emerge from the downslope end of covered trenches. Perhaps these trenches are rapidly filled by downward percolating rainfall, and, since the trench is quite porous and its shale walls are rather impervious, water tends to collect in the lower portion. When the trench is filled, water will flow from the lower end. One of these seeps is shown in Fig. 13.

Fig. 13. Seep Emerging from Covered Trench.

A summary of the activity detected at four seeps within the burial ground is presented in Table 4. Grab samples of water from these seeps were taken over periods of 2 to 6 months and analyzed for gross-beta and gross-alpha activity. The samples from Seep 2 were composited and analyzed for specific radionuclides and chemical ions. In addition, one sample from Seep 4 was analyzed for specific radionuclides. Mean gross-beta counts ranged from 1.7×10^2 counts $\text{min}^{-1} \text{ml}^{-1}$ at Seep 4 to 8 counts $\text{min}^{-1} \text{ml}^{-1}$ at Seep 1. Mean gross-alpha counts varied from 23 counts $\text{min}^{-1} \text{ml}^{-1}$ at Seep 4 to < 1 count $\text{min}^{-1} \text{ml}^{-1}$ at Seep 1. Identifiable contaminants from Seeps 2 and 4 include Sr^{90} , Cs^{137} , Zr^{95} - Nb^{95} , Co^{60} , and the rare earths. Seeps 1 and 2 are located in the northeastern part of the area, which was filled during the early years of operation; and Seeps 3 and 4 are located in the southwestern portion of the site, which contains the most recent burials (see Fig. 6).

Activity has also been noted in the intermittent stream that flows from the area into White Oak Creek. In addition to that contributed by surface seeps, some activity is transported by ground water through the weathered soil to points of discharge in or very near surface streams. This is particularly noticeable in the vicinity of well 185. Here contaminated water was observed to be seeping into the intermittent stream that flows through the area. The activity is believed to come from a covered trench located about 5 ft from the stream.

Grab samples of water in the stream were taken near well 191 about once each week during the period, August 22, 1959, to January 22, 1960. These samples show a mean gross-beta activity of 12 counts $\text{min}^{-1} \text{ml}^{-1}$ and a mean gross-alpha count of 23 counts $\text{min}^{-1} \text{ml}^{-1}$. Identifiable contaminants in the stream include Ru^{106} , Sr^{90} , Po^{210} , Pu^{239-40} , and the rare earths. A summary of the activity observed in the stream is presented in Table 4. In general,

Table 4. Summary of Activity Detected in Seeps and Stream

	Number of Samples Taken	Gross Activity ^a (counts/min/ml)					
		Max		Min		Mean	
		Gross β	Gross α	Gross β	Gross α	Gross β	Gross α
Seep 1	15	18	.3	3.2	.0	8	.1
Seep 2	17	85	6.5	4.9	.0	17	1.1
Seep 3	8	3.7×10^2	1.4×10^2	3.8	.0	1.6×10^2	18
Seep 4 ^b	4	5.2×10^2	3.2×10^2	37	1.9	1.7×10^2	23
Stream	17	23	1.0×10^2	4.3	.1	12	23

Radionuclides in Composite Sample (dis/min/ml)								
	Cs ¹³⁷	Co ⁶⁰	Sr ⁹⁰	Zr ⁹⁵ -Nb ⁹⁵	Ru ¹⁰⁶	TRE ^c	Po ²¹⁰	Pu ²³⁹⁻⁴⁰
Seep 2			85			1.30×10^2		
Seep 4 ^b	1.3×10^2	14	2.9×10^2	Trace		3.3×10^2		
Stream			42		2	60	Trace	Trace

^aGross beta counted at approximately 8% geometry. Gross alpha counted at approximately 47% geometry.

^bSpecific radionuclides from sample dated April 1, 1960 (alpha identification uncertain due to excess of solids in sample).

^cTotal rare earths counted at 22.3% geometry.

there is an increase in the concentration of activity in the samples taken during dry periods and a decrease in those taken during wet periods (see Fig. 14).

It was not practical to establish a continuous monitoring station and gaging station along this stream for detecting the amount of activity leaving the burial site. The intermittent nature of the stream and the marshy conditions that exist at its lower end are the prime reasons. In addition, the northeast section of the burial ground, which is contiguous with the flood plain of White Oak Creek, contributed surface runoff and ground water seepage directly to White Oak Creek. Thus, in order to determine the quantity of fission products leaving the site, it was necessary to monitor White Oak Creek.

White Oak Creek

Since White Oak Creek is contaminated by water from the Process Waste Water Treatment Plant, the Settling Basin, and other facilities, before it flows by the burial ground, it was necessary to install temporary monitoring stations along the creek immediately above and below the site to determine the amount, if any, of activity contributed by the burial ground to the creek (see Fig. 1). Water was pumped continuously from the creek at each station, and once each day a liter sample was taken from the collecting container. These daily samples were composited, usually in intervals of one week, and then analyzed for specific chemical and radionuclide content. A permanent continuous and proportional sampler is now installed at the downstream station.

In order to determine the difference in stream flow between the two sampling points, periodic discharge measurements were made with a Price pygmy meter at both sites. Of the six measurements, five showed increases, ranging from 8.7% to 0.8%, at the downstream station, while the sixth one showed a decrease of 1.4% in the discharge at the station below the burial ground. By plotting the six measured discharges (cfs) made at the upper station against

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Fig. 14. Gross Beta and Alpha Activity in Stream.

those made at the downstream station, and then constructing a trend line by the least squares method, it was possible to estimate the discharge for any period at the upstream station by knowing the discharge at the lower station (see Fig. 15). The total volume of water transported past the downstream monitoring station during sampling periods was obtained from the records of a permanent gaging station at this location operated by the Surface Water Branch of the U. S. Geological Survey. The distance between the two monitoring points was about 1/2 mile.

The analyses of creek water samples, collected between February 16, 1960, and May 25, 1960, showed that Burial Ground 4 contributed activity to White Oak Creek in quantities so small as to be undetectable. A summary of the radiochemical results for the sampling stations is presented in Table 5. Of ruthenium, cobalt, cesium, zirconium-niobium, the rare earths, and gross-alpha contaminants, there was less activity in the stream below the burial ground than above the site. There was a slight increase in strontium below the burial ground. However, by using the analysis of variance test on these data,⁵ it was found that at the 5% level of significance there was no difference between radionuclides detected at the stations.

In addition to radiochemical analyses, chemical analyses were performed on the samples to determine whether or not any chemical waste was being leached from the burial ground. Chemical results from the monitoring stations are summarized in Table 6. Slight differences were observed in the quantity of ions detected at the two stations, but, treated statistically at the 5% level of significance, the results for each station were not significantly different.

Fig. 15. Regression Line for Estimating Flow Above Burial Ground.

Table 5. Radioactivity Measured at Monitor Stations on White Oak Creek

Composite Date	Volume Discharge (gal)	Activity (mc)						
		Gross α	Sr ⁹⁰	Ru ¹⁰⁶	Cs ¹³⁷	Zr ⁹⁵ -Nb ⁹⁵	Co ⁶⁰	TRE
Upstream from Burial Ground 4								
	X 10 ³							
Feb. 16-19, 1960	60,495	10	309	206	206	21	206	980
Feb. 25 - Mar. 2, 1960	44,726	30	829	358	229	69	47	1,518
Mar. 8-14, 1960	45,824	16	359	367	305	172	164	1,055
Mar. 22-28, 1960	39,296	40	1173	3819	737	670	170	10,420
Mar. 29 - Apr. 3, 1960	66,571	22	568	454	227	227	114	1,873
Apr. 6-12, 1960	33,867	23	92	0	0	0	0	364
Apr. 19-25, 1960	22,686	15	116	182	85	0	553	236
Apr. 25 - May 3, 1960	26,433	9	586	234	423	0	252	1,050
May 12-18, 1960	17,127	3	67	79	35	0	129	158
May 19-25, 1960	19,517	8	131	174	218	12	83	449
Totals	376,542	176	4230	5873	2465	1171	1718	18,153
Downstream from Burial Ground 4								
Feb. 16-19, 1960	61,400	10	419	314	314	105	209	1,362
Feb. 26 - Mar. 2, 1960	46,405	32	1108	364	190	32	47	1,194
Mar. 8-14, 1960	47,181	16	418	378	322	145	161	869
Mar. 22-28, 1960	40,524	42	1037	3039	553	553	207	6,626
Mar. 29 - Apr. 3, 1960	67,863	12	579	810	347	231	116	1,793
Apr. 6-12, 1960	35,094	12	156	0	0	0	0	377
Apr. 19-25, 1960	23,398	16	160	136	60	0	535	287
Apr. 25 - May 3, 1960	27,984	10	573	229	253	0	229	1,026
May 12-18, 1960	18,485	3	95	79	28	0	139	199
May 19-25, 1960	21,876	7	444	160	160	22	67	545
Totals	390,210	160	4989	5509	2227	1088	1710	14,238

Table 6. Chemical Analysis of Stream Samples Taken at Monitor Stations on White Oak Creek
(milligrams per liter)

Date	Total Solids	Total Hardness	Fe	Ca	NC ₃	SO ₄	PO ₄	Cl	Na
Upstream from Burial Ground 4									
Feb. 16-19, 1960	260	128	3.4	34		27	0.9	7	10
Feb. 25 - Mar. 2, 1960	65	126	< 0.05	30	< 0.05	10	< 0.05	8	20
Mar. 8-14, 1960	94	124	< 0.05	11		33	0.4	7	14
Mar. 22-28, 1960	136	120	0.3	33		29	1.2	7	14
Mar. 29 - Apr. 3, 1960	220	119	1.6	31		24	0.4	4	9
Apr. 6-12, 1960	64	125	< 0.05	29	0.9	5	0.1	5	18
Apr. 19-25, 1960	130	88	< 0.05	1	< 0.05	25	0.1	12	18
Apr. 25 - May 3, 1960	160	98	< 0.05	< 0.05	< 0.05	35	0.2	8	25
May 12-18, 1960	110	105	< 0.05	10	1.1	35	< 0.05	10	30
May 19-25, 1960	100	110	< 0.05	25	< 0.05	30	< 0.05	5	25
Downstream from Burial Ground 4									
Feb. 16-19, 1960	240	122	3.8	30		30	1.2	5	8
Feb. 26 - Mar. 2, 1960	86	120	< 0.05	35	< 0.05	10	< 0.05	8	20
Mar. 8-14, 1960	69	122	< 0.05	18		33	0.3	8	14
Mar. 22-28, 1960	240	120	0.4	30		20	1.1	5	10
Mar. 29 - Apr. 3, 1960	235	120	0.7	34		20	0.2	5	10
Apr. 6-12, 1960	84	105	< 0.05	26	< 0.05	5	0.1	6	18
Apr. 19-25, 1960	150	98	< 0.05	1	< 0.05	35	0.1	13	15
Apr. 25 - May 3, 1960	180	94	< 0.05	> 0.05	< 0.05	30	0.1	11	25
May 12-18, 1960	110	110	< 0.05	20	1.1	35	< 0.05	10	25
May 19-25, 1960	110	110	< 0.05	30	4.7	35	< 0.05	5	25

CONCLUSIONS

Water-level measurements, taken about once each week from August 17, 1959, to April 29, 1960, indicate that the water table fluctuates between 2 ft to 3 ft below the surface in low areas of the burial ground and 10 ft to 15 ft beneath higher elevations. Thus, solid waste is in contact with ground water during most periods of the year.

Activity has been detected in water samples from eight of the sixteen wells located within the burial ground. Most of the contaminated wells are located in areas of low topography where ground water contact with the waste is greatest. The movement of radioactivity to wells from submerged trenches reflects the leaching of fission products from contaminated solids. Radionuclides have also been found in seeps and streams in the area. Many seeps are believed to emerge from the downslope end of covered trenches. In addition to the activity reaching surface streams from seeps, soluble waste material is transported by ground water through the weathered soil to points of discharge in or near surface streams. This is particularly noticeable in the case of trenches that are located very near to streams. Identifiable contaminants from wells, seeps, and streams within the area include Zr^{95} - Nb^{95} , Ru^{106} , Cs^{137} , Co^{60} , Sr^{90} , Po^{210} , Pu^{239-40} , and the rare earths.

Although radionuclides have been detected in wells, seeps, and streams in Burial Ground 4, the amount of activity contributed to White Oak Creek during the sampling period was so small in comparison to that already present that it could not be detected. While the rate of leaching of fission products from solid waste by ground water is not known, it is believed to be small. There

was only a small increase in the concentration of stable cations in the ground water.

The permanent monitoring station now installed at the stream gaging station downstream from Burial Ground 4 will aid in detecting any increase in activity entering White Oak Creek from the site.

From this study it is seen that ground water will leach some of the radioactive nuclides from buried solid waste and transport a part of the activity through the soil to points in or near surface streams. Trenches that lie in low areas where the water table intersects the buried waste and/or surface water drainage is poor are in particularly unfavorable locations. Also trenches that lie within a few feet of surface streams allow fission products to escape to surface streams after only a few feet of movement through the soil.

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