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EVALUATION OF ISOTOPE MIGRATION - LAND BURIAL

WATER CHEMISTRY AT COMMERCIALLY OPERATED LOW-LEVEL RADIOACTIVE WASTE DISPOSAL SITES

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SUMMARY

Water samples were collected by anoxic procedures from trenches 2, 19S, 26, 27, 32, 33L-4, and 33L-18 and from well UB1-A at the Maxey Flats, Kentucky, low-level radioactive waste disposal site. In-situ measurements of pH, Eh, specific conductance, dissolved oxygen, and temperature were made. The results of inorganic, organic, and radiochemical analyses are reported. Acid-base titration curves of the trench waters exhibit the complex nature of these waters compared to well water.

The population distribution of aerobic bacteria, anaerobic bacteria, denitrifiers, sulfate-reducers, and methanogens in trench water and well water samples from Maxey Flats are presented. Several colonies of bacteria from aerobic and anaerobic agar plates were isolated and identified including: Bacillus sp, Pseudomonas sp, Citrobacter sp, and Clostridium sp. The effect of varying concentrations of radionuclides on the growth of a mixed culture bacteria from trench 32 is described.

Cobalt-60, strontium-90, tritium, and plutonium-238, 239, 240 were found in all trench waters. Americium-241 and cesium-137 were found in most trenches, whereas cesium-134 was found only in trench 33L-18. Several members of the U-238 and Th-232 decay series were measured in trenches 27 and 33L-18.

Gas chromatograms and concentrations of organic compounds present in the water samples from Maxey Flats are shown. A comparison of organic compounds and radionuclides identified in water from well UB1 with those measured in nearby trenches suggests water communication between the trenches and the well to a depth of 30 feet.

Radiochemical analyses of suspended particulates filtered from trench waters taken from the West Valley, New York, disposal site during November 1977 are also reported.

1. INTRODUCTION

The results of inorganic, organic, and radiochemical analyses of dissolved constituents in water samples obtained from the West Valley, New York, low-level radioactive waste disposal site on November 8-10, 1977 have been reported.[1] These trench water samples were filtered through 0.45 micron cellulose membrane under anoxic conditions. Radiochemical analyses of suspended particulates filtered from the trench waters are reported here.

Water samples were collected anoxically from trenches 2, 26, and 32 at the Maxey Flats, Kentucky, disposal site on July 19, 1977 primarily for microbiological studies. Microbial population distributions, growth characteristics of microorganisms, and preliminary characterization of the dissolved inorganic, organic, and radiochemical species in these samples were previously reported.[2] A summary of all analyses performed on these samples to date is given in this report.

Additional water samples from Maxey Flats were collected anoxically from trenches 19S, 27, 33L-4, and 33L-18 on May 16-16, 1978. These trenches were selected based on their locations, and on the values of pH, specific conductance, dissolved organic carbon, alpha, beta, gamma, and tritium activities measured in the survey study of the disposal site.[3,4] Inorganic, organic, and radiochemical analyses of these samples are given.

In the fall of 1977, personnel from the U.S. Geological Survey drilled five observation wells (UB1, UB1-A, UB2, UB3, and UB4) adjacent to burial trenches at the Maxey Flats site as shown in Figure 1.[5] These wells were drilled to various depths as part of a study of site hydrology. In the process of drilling well UB1, contaminated water that had an organic odor characteristic of trench water was encountered. The recharge rate of the well was rapid with 15 to 20 gallons of water accumulating at the bottom of the well overnight.[6] Samples of the contaminated water from well UB1 were collected oxically and filtered by USGS personnel and then sent to BNL for analysis. Subsequently, well UB1 was grouted with cement to a depth of 30 feet to seal off the zone of contamination and then finished to a depth of 70 feet. Well UB1 in its present state is virtually dry.

Well UB1-A was drilled adjacent to well UB1 to a depth of 15 feet, cased, grouted, and then completed to 25 feet. Well UB1-A contained water and was

sampled anoxically on May 16, 1978. Results of analyses of UB1-A are reported together with results of analyses of samples from trenches 19S, 27, 33L-4, and 33L-18.

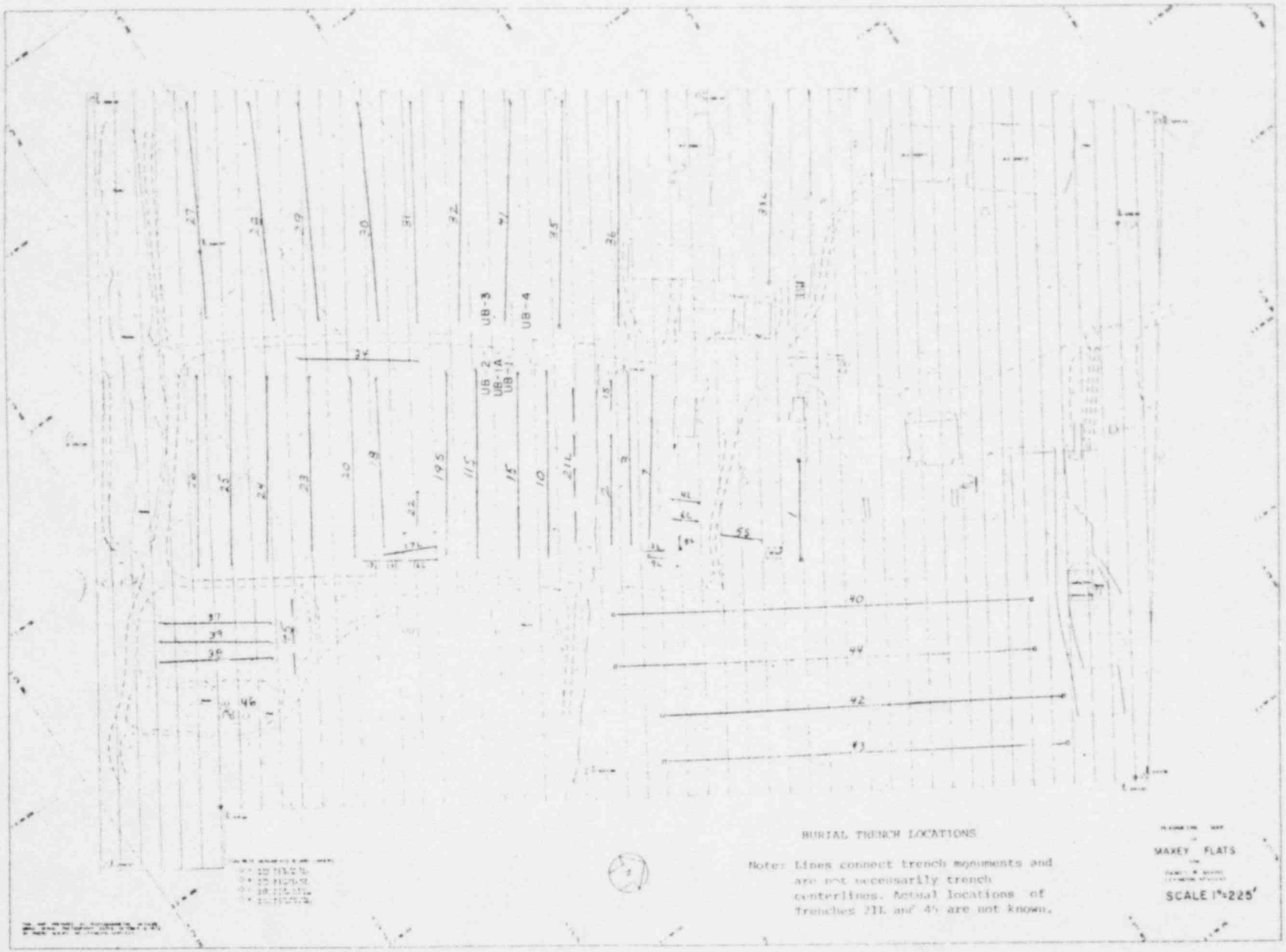

Figure 1. Sketch of Maxey Flats, Kentucky, radioactive waste disposal site trench locations.[5]

II. SAMPLING AND FIELD MEASUREMENTS (G.G. Galdi and S. L. Garber)

The procedures for collecting and filtering trench water under anoxic conditions and for in-situ measurements have been described.[1,7] In-situ measuremnts of color, pH, Eh, specific conductance, and temperature of the water samples collected from trenches 2, 26, and 32 at Maxey Flats are given in Table 1.

Water collected anoxically from trench 32 was filtered anoxically within 24 hours after collection and analyzed for ammonia with a gas sensing probe. The measured concentration of nitrogen as ammonia was 112 mg/l. The same filtered sample (in a sealed bottle) reanalyzed three months later by the same method contained 114 mg/l nitrogen as ammonia. In addition, ammonia analyses were performed on freshly filtered samples of water from trenches 2, 26, and 32, (which had been stored in an anoxic condition at $\sim 4^{o}C$), by both the probe method and the Berthelot-colorimetric method. The results of the ammonia analyses summarized in Table 2 indicate that the filtered sample was not affected by storage and that the two analytical methods are comparable.

In-situ measurements of water samples collected from trenches 19S, 27, 33L-4, 33-18, and from well UB1-A are given in Table 3. Due to instrumental problems in the field, specific conductance was not determined on all the trenches by the in-line probe, but was measured on another water sample by USGS personnel in the field, immediately after collecting the sample.

Table 1

In-Situ Measurements of Trench Water Samples Taken from Maxey Flats, Kentucky, Disposal Site, July 1977

Sampling Location	Color	pH	Eh (mV, NHE)[a]	Specific Conductance (μmhos/cm @ 25°C)	Temp. (°C)
Trench 2	Yellow	7.4	90	3200	15.0
Trench 26	Gray	7.3	130	2680	20.8
Trench 32	Gray	7.9	10	5650	17.2

[a] Field measurements of redox potential are reported relative to the normal hydrogen electrode (NHE).

Table 2

Ammonia Analyses of Trench Water Samples Taken from Maxey Flats, Kentucky, Disposal Site, July 1977

Trench Sample	Analysis Location	Concentration of Ammonia-Nitrogen (mg/l)	
		Probe	Berthelot Reaction
2	Laboratory	36	39
26	Laboratory	115	99
32	Laboratory	117	99
32	Field[a]	112	--
32	Laboratory[b]	114	--

[a] Sample filtered in the field within 24 hours of collection and analyzed immediately.

[b] From same filtered sample as (a) but analyzed 3 months later.

Table 3

In-Situ Measurements of Water Samples Taken from Maxey Flats, Kentucky, Disposal Site, May 1978

Sampling Location	Color	pH	Eh (mV, NHE)[a]	Temp. (°C)	Dissolved Oxygen (ppm)	Specific Conductance (μmhos/cm @ 25°C)
Trench 19S	Light Green	6.9	25	12.4	0.2	2310
Well UB1-A	White Cloudy	6.6	274	13	6.8	3620
Trench 27	Light Green	6.6	17	17.6	0.05	9370[b]
Trench 33L-4	Light Yellow-Green	12.1	-7	12.0	4.1[c]	5580[b]
Trench 33L-18	Pale Green	2.4	520	10.7	0.25	9390[b]

[a] Field measurements of redox potential are reported relative to the normal hydrogen electrode (NHE).

[b] Analyses performed by USGS personnel in the field immediately after collecting sample.

[c] Result of low water level; air in lines.

III. INORGANIC ANALYSES (S. L. Garber and R. Miller)

A summary of the methods used to measure the dissolved chemical constituents in trench waters was described in a previous report.[1]

Maxey Flats, -July 1977

The concentrations of dissolved non-metals in water samples from trenches 2, 26, and 32 at Maxey Flats are given in Table 4. Alkalinity titrations with standard acid were performed to a pH 4.5 end point. Calculation of bicarbonate cencentration from a total alkalinity measurement is not possible in a buffered trench water system and is not reported here.

The concentrations of dissolved metals found in water samples from trenches 2, 26, and 32 are given in Table 5. In the calculation of total dissolved cations (meg/l), iron is considered to be as Fe^{+2} and nitrogen as NH_4^+ from table 4 is included.

Maxey Flats, -May 1978

The change in pH of filtered water samples from trenches 19S, 27, 33L-4, 33L-18 and well UB1-A with incremented addtions of acid and base is given in Table 6 and shown on Figure ?. Standard 0.1N HCL and 0.1N NaOH were added to 25 ml water sample aliquots immediately after filtration. The titration curve of water from well UB1-A resembles that of a typical simple ground water. The shapes of the trench water titration curves indicate complex water systems similar to the water samples from West Valley, New York.[1] Because the initial pH of the water sample from trench 33L-18 is 1.9, an alkalinity titration is not applicable.

The concentration of dissolved non-metals in the water samples are shown in Table 7. The probe method of analyzing for fluoride is sensitive to the presence of complexing agents which can combine with the F^- and consequently reduce the measured F^- values. When the fluoride concentation, as measured by standard addition, is higher than by direct measurement, there is reason to suspect the presence of complexing agents. Although the trenches show higher fluoiride concentrations by standard addition, the concentration of F^- in trench 33L-18 could not be determined by the standard additions method. The added F^- was not available for analysis presumable due to the presence of an excess of complexing

material.

The 2000 mg/l of nitrogen (NO_2^- + NO_3^-) measured in trench 33L-18 is predominantly in the NO_3^- form with ~4 mg/l present as NO_2^-. It is presumed that liquid waste was solidified with urea formaldehyde in-situ in this trench. This polymerization is acid catalyzed and could be the source of the low pH measured in the trench water. Sulfuric acid is commonly used as the catalyst for urea formaldehyde polymerization and the high sulfate concentration (1000 mg/l) in the trench water could have resulted from the postulated polymerization. Although nitric acid is not generally used, if it had been, that could be the source of the high NO_3^- concentration found. This does not exclude the possibility that nitrates were in the buried waste.

The concentrations of dissolved metals found in the water samples collected from Maxey Flats are given in Table 8. It is presumed that liquid waste was solidified with cement in-situ in trench 33L-4, which is the reason for the high pH measured in the trench water. Consequently the concentration of dissolved calcium is high and cations such as iron and magnesium are low.

A semi-quantitative search for mercury in trench water samples by conventional atomic absorption analysis indicated the presence of mercury in trench 27. A cold vapor flameless atomic absorption procedure was used to determine the mercury with greater accuracy. Volatile organic compounds in the water, which interfered with the analyses, were decomposed by oxidative digestion using potassium permanganate and potassium persulfate. Using the method of standard additions, 7.5 mg/l of mercury was measured in the trench 27 water sample.

Table 4

Concentration of Dissolved Non-Metals in Trench Water Samples Taken from Maxey Flats, Kentucky, Disposal Site, July 1977[a]

Dissolved Component	Trench 2	Trench 26	Trench 32
Total Alkalinity (as $CaCO_3$)	1370	860	2600
Inorganic Carbon	330	100	380
DOC	90	770	990
Hardness (Ca+Mg) (as $CaCO_3$)	170	360	1300
Residue (180°C)	2740	1150	3590
Chloride	230	210	580
Nitrogen (N) (NH_3-probe)	36	115	117
Nitrogen (N) (NH_4^+-color)	39	99	99
Nitrogen (N) ($NO_2^-+NO_3^-$)	0.08	<0.04	<0.04
Phosphate	<0.5	1.0	24
Silica	12	6.5	10
Sulfate	<5	<1	<1
Total Anions (meq/l)	34	28	68

[a] Concentration given in mg/liter.

Table 5

Concentration of Dissolved Metals in Trench Water Samples Taken from Maxey Flats, Kentucky, Disposal Site, July 1977[a]

Metal	Trench 2	Trench 26	Trench 32
Calcium	20	45	65
Cesium	<0.1	0.2	<0.1
Iron	28	110	32
Lithium	1.3	0.15	0.23
Magnesium	41	87	320
Potassium	35	27	280
Sodium	1300	270	1900
Total Cations[b] (meq/l)	66	34	130

(a) Concentrations given in mg/liter.

(b) Includes nitrogen as NH_4^+. Iron was considered to have been as Fe^{+2}.

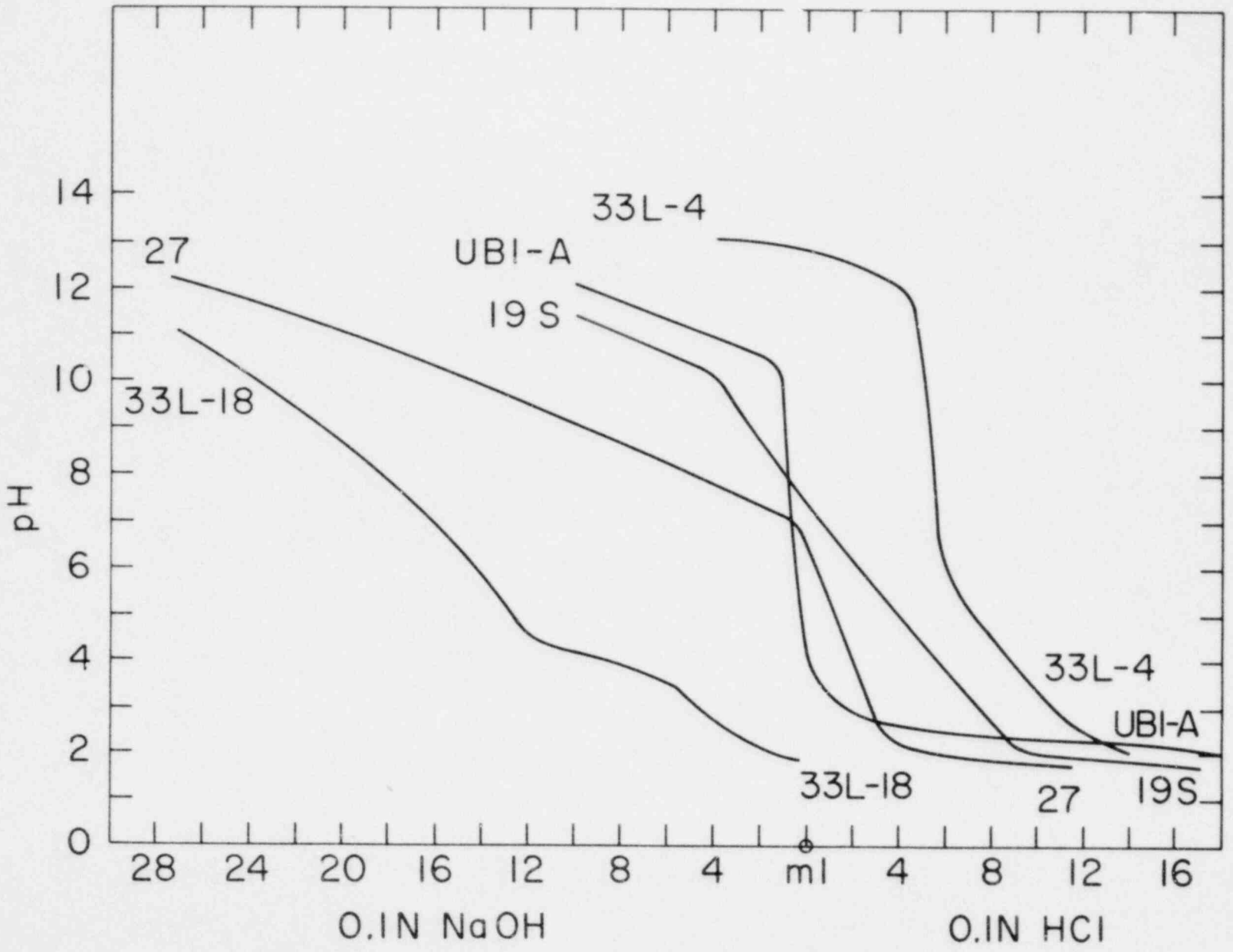

Figure 2. Acid-base titration curves of water samples from Maxey Flats, Kentucky disposal site, May 1978.

Table 6

Acid-Base Titration of Water Samples Taken from Maxey Flats, Kentucky, Disposal Site, May 1978

Trench 19S		Trench 27		Trench 331-4	
Acid[(a)] (ml)	pH	Acid[(a)] (ml)	pH	Acid[(a)] (ml)	pH
0.0	7.1	0.0	6.6	0.0	12.8
1.0	6.9	1.0	5.8	1.2	12.8
2.3	6.2	1.7	4.5	2.0	12.7
3.5	5.5	2.0	4.0	3.1	12.4
4.5	4.8	3.3	2.5	3.9	12.2
4.6	4.5	4.0	2.3	5.0	11.7
5.3	4.5	5.7	2.0	5.1	10.9
6.1	3.7	11.8	1.8	5.5	9.0
8.6	2.4			6.0	6.4
10.8	2.1			6.1	6.1
12.8	1.9			7.8	4.7
16.8	1.8			9.0	4.1
				11.0	2.8
				15.0	1.7

Base[(a)] (ml)	pH	Base[(a)] (ml)	pH
0.0	7.1	0.0	6.6
1.6	8.4	1.0	7.0
2.6	9.6	2.0	7.4
4.0	10.3	3.0	7.7
8.0	11.0	4.0	7.9
9.9	11.4	5.0	8.0
		10.0	9.0
		15.0	10.1
		20.0	11.2

(Continued next page)

Table 6 (Cont'd)

Acid-Base Titration of Water Samples Taken from
Maxey Flats, Kentucky, Disposal Site, May 1978

Trench 33L-18		Well UB1-A	
Base[a] (ml)	pH	Acid[a] (ml)	pH
0.0	1.9	0.0	6.5
0.9	2.0	0.2	4.5
1.7	2.2	0.3	3.6
3.0	2.4	0.5	3.6
4.6	3.0	3.2	2.7
5.1	3.2	4.0	2.7
5.4	3.4	6.8	2.5
6.0	3.4	18.1	1.9
6.5	3.5		
7.7	3.8		
8.5	4.1		
9.4	4.1	Base (ml)	pH
10.0	4.2		
10.2	4.3	0.0	6.5
11.0	4.4	0.8	10.4
11.5	4.5	1.8	10.6
13.0	5.1	3.0	10.8
14.1	5.9	3.9	10.9
15.8	6.9	5.6	11.3
17.2	7.5	8.5	11.9
18.3	8.1		
19.9	8.6		
25.0	10.4		

[a] Titration of 25 ml of filtered water sample with 0.1N HCL and 0.1N NaOH.

Table 7

Concentration of Dissolved Non-Metals in Water Samples Taken from Maxey Flats, Kentucky, Disposal Site, May 1978[a]

Dissolved Component	Trench 19S	Well UB1-A	Trench 27	Trench 33L-4	Trench 33L-18
Total Alkalinity (as $CaCO_3$)	910	50	330	1600	--[b]
Inorganic Carbon	70	7.4	<2	10	100
DOC	500	7.3	540	1100	5600
Hardness (Ca+Mg) (as $CaCO_3$)	810	1300	1900	1600	120
Residue (180°C)	2100	3360	8400	4960	5600
Chloride	140	300	3900	170	140
Nitrogen (N) (NH_3-Probe)	4.1	<1	80	18	<1
Nitrogen (N) ($NO_2^- + NO_3^-$)	<0.1	<0.1	<0.1	11	2000
Fluoride (Direct Reading)	0.8	0.5	0.4	<0.1	0.9
Fluoride (Standard Addition)	1.0	0.7	0.9	0.2	--[c]
Phosphate	<2	<3	17	<2	<2
Silica	9	14	5	1	130
Sulfate	<5	1200	<5	<5	1100
Total Anions (meq/l)	19	35	116	32	174

(a) Concentration given in mg/liter.

(b) Initial pH of 1.9 does not allow an alkalinity titration.

(c) F^- added was not available for analysis - presumably tied up as a complex.

Table 8

Concentration of Dissolved Metals in Water Samples Taken from Maxey Flats, Kentucky, Disposal Site, May 1978[a]

Metal	Trench 19S	Well UB1-A	Trench 27	Trench 33L-4	Trench 33L-18
Calcium	50	160	240	650	44
Cesium	0.1	<0.05	<0.05	<0.05	0.1
Iron	120	<0.01	1200	0.3	190
Lithium	0.38	0.44	1.9	0.16	0.50
Magnesium	120	220	260	0.08	18
Manganese	0.42	0.14	88	<0.05	26
Potassium	12	4	36	30	14
Sodium	650	500	450	180	190
Strontium	0.53	2.5	3.8	7.0	<0.1
Total Cations[b] (meq/l)	45	49	104	41	21

[a] Concentration given in mg/liter.

[b] Nitrogen as NH_4^+ from Table 7 is included in the total cations.

IV. ORGANIC ANALYSIS (A.J. Francis and B. Nine)

Water samples collected from wells UB1 and UB1-A and from trenches 19S, 26, 27, 32, 33L-4 and 33L-18 at the Maxey Flats, Kentucky, disposal site were analyzed for dissolved organic carbon (DOC) and for various dissolved organic constituents. The methylene chloride extraction scheme used to isolate acidic, neutral, and basic organic compounds from these waters was described in a previous report.[1]

The concentration of dissolved inorganic and organic carbon in these water samples are shown in Table 9. The DOC concentration in the trenches ranged from 500 mg/l to 5600 mg/l. The DOC in well UB1 (210 mg/l) is significantly higher than the 8 mg/l measured in well UB1-A, a level that is normally encountered in many unpolluted well waters.

Results of the GC/MS[1] analyses of the water samples are presented in Figures 3 to 10 and Tables 10 to 17. Each figure shows the gas chromatograms for the acidic, neutral, and basic fractions obtained by methylene chloride extraction of water from a single trench or well. Not all peaks seen in a set of chromatograms from a single sample were identified. Those which were identified are numbered, and their concentrations are listed in the tables. Concentrations reported here have not been corrected for solvent extraction efficiency or for possible matrix effects in these complex solutions.

The same types of organic compounds that were identified in water samples from the West Valley, New York, disposal site [1] are seen in the water samples from Maxey Flats. However, differences were observed in the organic constituents among the trenches and between the two disposal sites.

Table 9

Concentration of Dissolved Carbon in Water Samples Taken from Maxey Flats, Kentucky, Disposal Site[a]

Sampling Location	Collection Date	Inorganic Carbon	Organic Carbon
Well UB1	10/77	100	210
Well UB1-A	5/78	7	8
Trench 19S	5/78	70	500
Trench 26	7/77	100	770
Trench 27	5/78	<2	540
Trench 32	7/77	380	990
Trench 33L-4	5/78	10	1100
Trench 33L-18	5/78	100	5600

[a]Concentration given in mg/liter.

Table 10

Concentration of Dissolved Organic Compounds Identified in Trench 19S Water Sample from Maxey Flats, Kentucky, Disposal Site[a]

Peak Number	Compound	Concentration mg/l
Acidic Fraction:		
1	2-Methyl propionic acid	0.40
2	2-Methyl butanoic acid	4.6
3	3-Methyl butanoic acid	1.8
4	Valeric acid	2.0
5	3-Methyl pentanoic acid	3.1
6	C_6 branched acid[b]	0.35
7	Hexanoic acid	1.5
8	2-Methyl hexanoic acid	1.5
9	Cresol	2.9
10	2-Ethyl hexanoic acid	5.6
11	C_8 branched acid[c]	0.72
12	C_8 branched acid[c]	0.68
13	Benzoic acid	0.22
14	Octanoic acid	0.36
15	Phenyl acetic acid	0.56
16	Phenyl propionic acid	1.2
17	Phenyl hexanoic acid	N.Q.[d]
Neutral Fraction:		
1	p-Dioxane	N.Q.
2	Methyl isobutyl ketone	0.56
3	Toluene	2.9
4	Xylene (isomer)	N.Q.
5	Xylene (isomer)	N.Q.
6	Cyclohexanol	2.9
7	Xylene (isomer)	N.Q.
8	Dibutyl ketone	N.Q.
9	Fenchone	0.03
10	Triethyl phosphate	0.38
11	Naphthalene	0.12
12	Tributyl phosphate	0.16

[a] Key to Figure 3.

[b] Quantified using 3-Methyl pentanoic acid standard.

[c] Quantified using 2-Ethyl hexanoic acid standard.

[d] Not quantified.

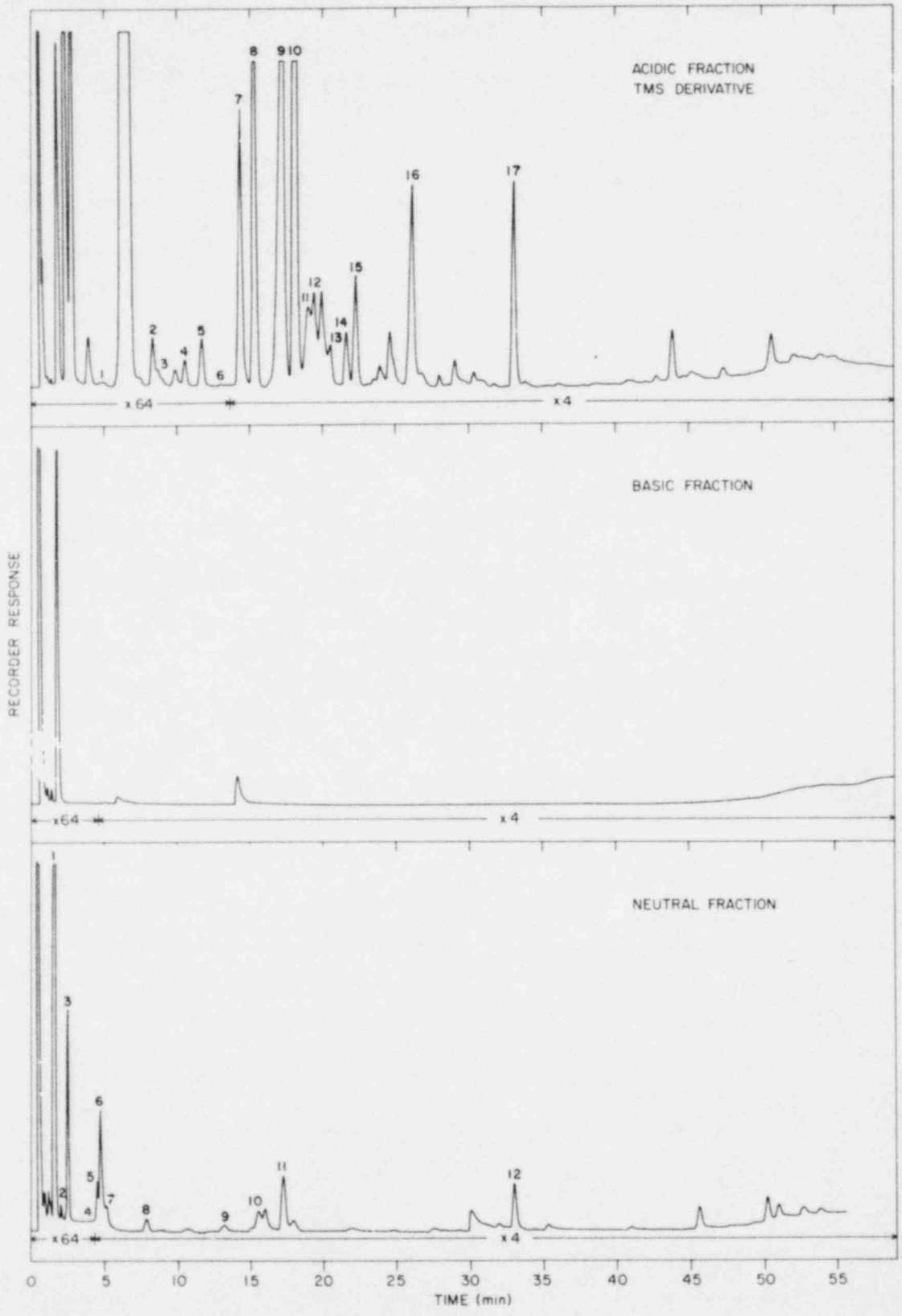

Figure 3. Gas chromatogram of methylene chloride extract of Maxey Flats trench 19S water sample.

Table 11

Concentration of Dissolved Organic Compounds Identified in Trench 26 Water Sample from Maxey Flats, Kentucky, Disposal Site[a]

Peak Number	Compound	Concentration mg/l
Acidic Fraction:		
1	2-Methyl propionic acid	3.6
2	2-Methyl butanoic acid	18.5
3	Pentanoic acid	4.6
4	3-Methyl pentanoic acid	4.2
5	Hexanoic acid	1.9
6	2-Methyl hexanoic acid	1.2
7	Cresol (isomers)	2.0
8	2-Ethyl hexanoic acid	3.4
9	Benzoic acid	1.2
10	Phenyl acetic acid	1.5
11	Phenyl propionic acid	1.3
Neutral Fraction:		
1	p-Dioxane	N.Q.[b]
2	Toluene	3.5
3	Naphthalene	0.28
4	α-Terpineol	0.31

[a] Key to Figure 4.

[b] Not quantified.

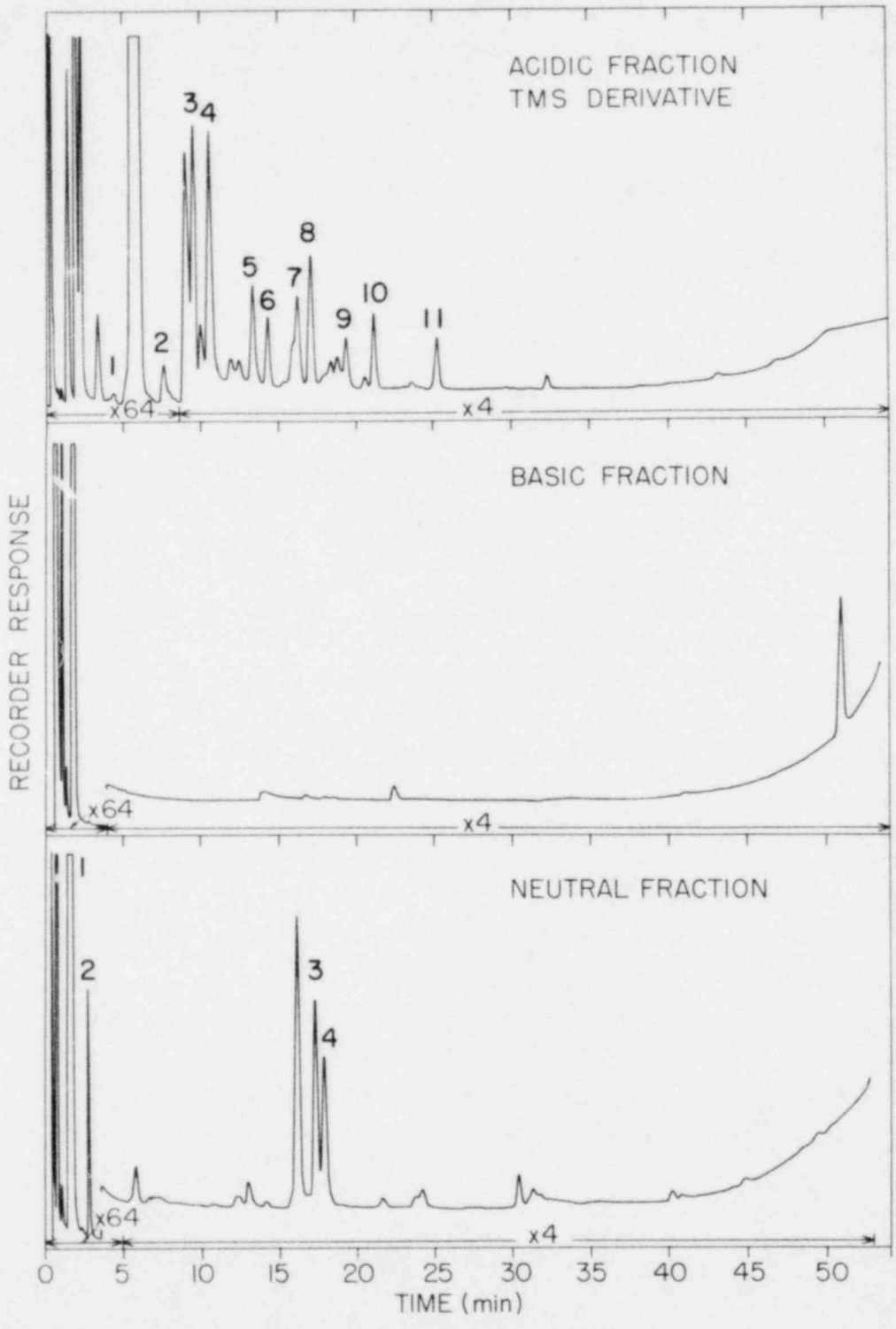

Figure 4. Gas chromatogram of methylene chloride extract of Maxey Flats trench 26 water sample.

Table 12

Concentration of Dissolved Organic Compounds Identified in Trench 27 Water Sample from Maxey Flats, Kentucky, Disposal Site[a]

Peak Number	Compound	Concentration mg/l
Acidic Fraction:		
1	2-Methyl butanoic acid	0.98
2	3-Methyl butanoic acid	0.48
3	C_6 branched acid[b]	0.66
4	Phenol	0.40
5	Hexanoic acid	1.2
6	2-Methyl hexanoic acid	0.40
7	C_8 acid	N.Q.
8, 9	Cresol (isomers)	0.70
10	2-Ethyl hexanoic acid	16.7
11	C_8 branched acid[c]	0.03
12	C_8 branched acid[c]	0.03
13	Benzoic acid	0.22
14	Octanoic acid	0.64
15	Phenyl acetic acid	0.08
16	Phenyl propionic acid	0.56
17	Phenyl hexanoic acid	N.Q.[d]
Neutral Fraction:		
1	p-Dioxane	N.Q.
2	Toluene	3.4
3	Bis(2-ethoxyethyl) ether	N.Q.
4	2-Ethyl-1-hexanol	0.23
5	Fenchone	N.Q.
6	Triethyl phosphate	N.Q.
7	Camphor	N.Q.
8	Naphthalene	0.15

[a] Key to Figure 5.

[b] Quantified using 3-Methyl pentanoic acid standard.

[c] Quantified using 2-Ethyl hexanoic acid standard.

[d] Not quantified.

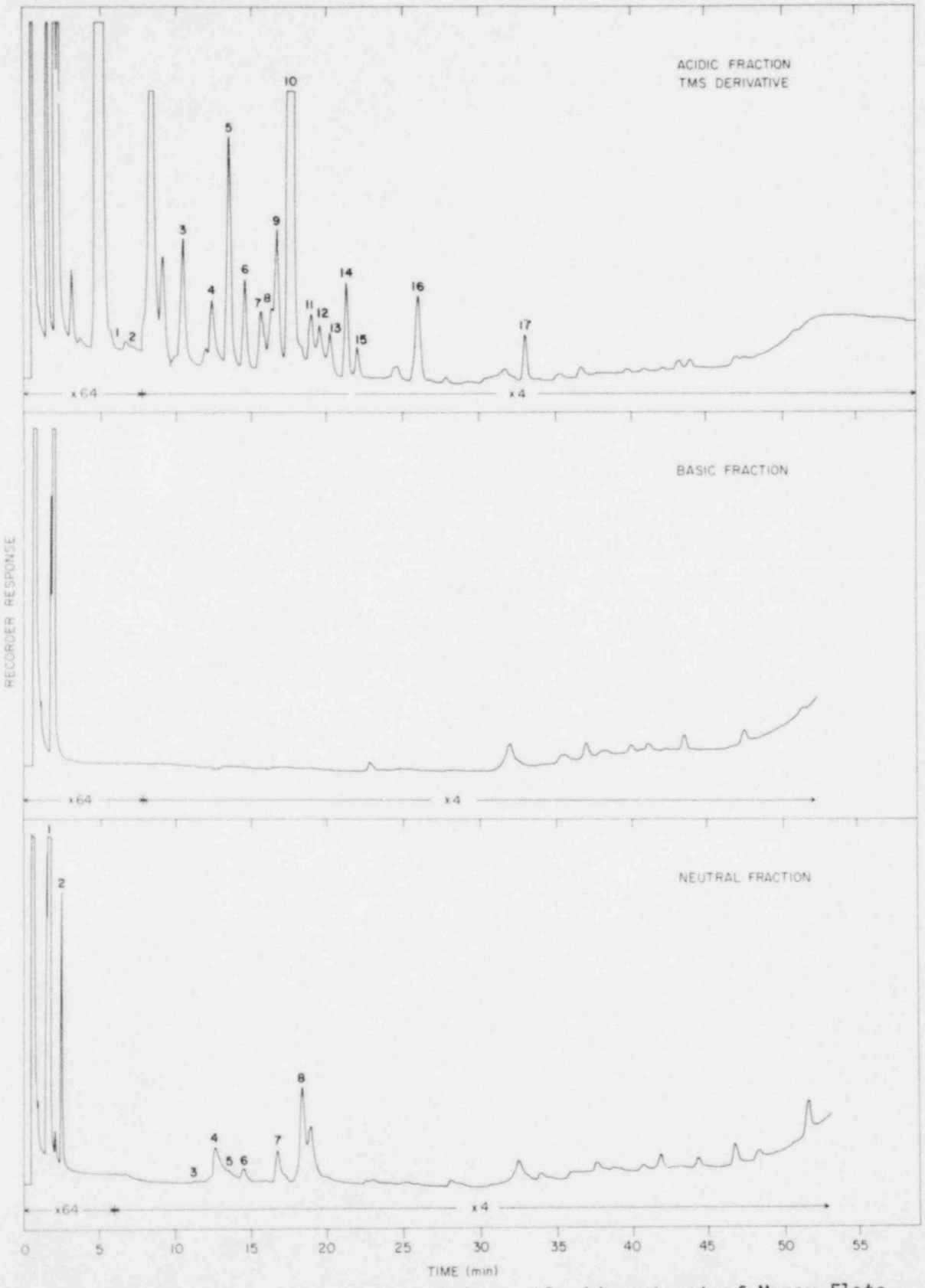

Figure 5. Gas chromatogram of methylene chloride extract of Maxey Flats trench 27 water sample.

Table 13

Concentration of Dissolved Organic Compounds Identified in Trench 32 Water Sample from Maxey Flats, Kentucky, Disposal Site[a]

Peak Number	Compound	Concentration mg/l
Acidic Fraction:		
1	Isobutyric acid	2.0
2	2-Methyl butyric acid	12.7
3	3-Methyl butyric acid	5.8
4	Pentanoic acid	4.7
5	2-Methyl pentanoic acid[b]	4.0
6	3-Methyl pentanoic acid	1.4
7	Phenol	1.2
8	Hexanoic acid	4.7
9	2-Methyl hexanoic acid	3.2
10	Cresol (isomers)	4.2
11	2-Ethyl hexanoic acid	8.8
12	Benzoic acid	1.9
13	Octanoic acid	1.3
14	Phenyl acetic acid	3.4
15	Phenyl propionic acid	9.8
16	Phenyl hexanoic acid	N.Q.[c]
17	Phthalate	N.Q.
Neutral Fraction:		
1	p-Dioxane	N.Q.
2	Toluene	7.0
3	Xylene	0.48
4	Cyclohexanol	0.24
5	Naphthalene	0.28
6	α-Terpineol	0.49
7	Tributyl phosphate	0.36

[a] Key to Figure 6.

[b] Quantified using 3-Methyl pentanoic acid standard.

[c] Not quantified.

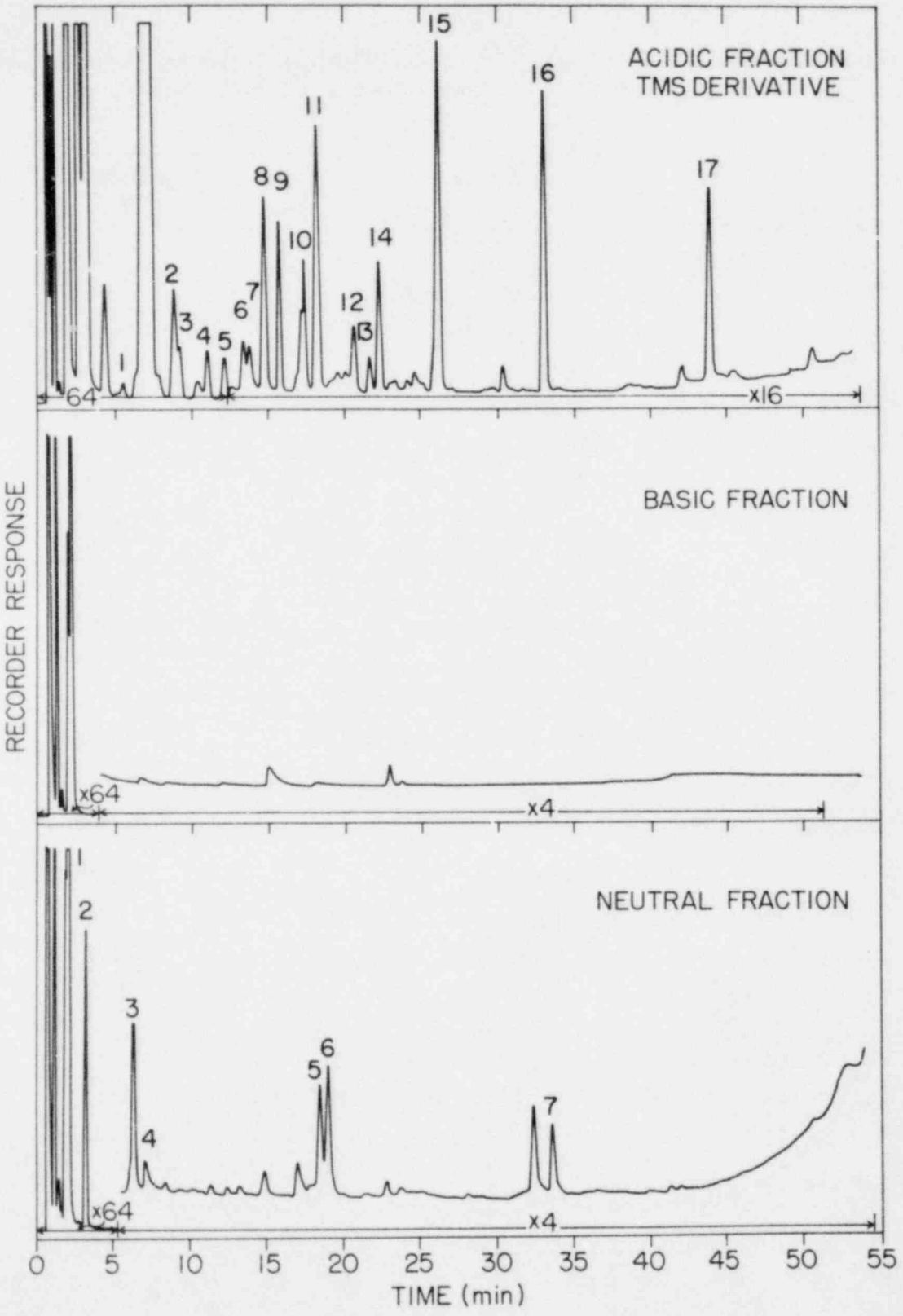

Figure 6. Gas chromatogram of methylene chloride extract of Maxey Flats trench 32 water sample.

Table 14

Concentration of Dissolved Organic Compounds Identified in Trench 33L-4 Water Sample From Maxey Flats, Kentucky, Disposal Site[a]

Peak Number	Compound	Concentration mg/l
Acidic Fraction:		
1	3-Methyl butanoic acid	1.6
2	Valeric acid	1.3
3	C_6 branched acid[b]	0.74
4	C_6 branched acid[b]	0.41
5	Phenol	0.20
6	Hexanoic acid	2.0
7	2-Methyl hexanoic acid	0.30
8	Cresol (isomers)	0.28
9	2-Ethyl hexanoic acid	27.4
10	Benzoic acid	0.59
11	Octanoic acid	0.39
12	Phenyl acetic acid	0.25
13	Phenyl propionic acid	0.70
14	Vanillin	8.6
Neutral Fraction:		
1	p-Dioxane	N.Q.[c]
2	Toluene	0.39
3	Cyclohexanol	1.1
4	2-Ethyl-1-hexanol	N.Q.

[a] Key to Figure 7.

[b] Quantified using 3-Methyl pentanoic acid standard.

[c] Not quantified.

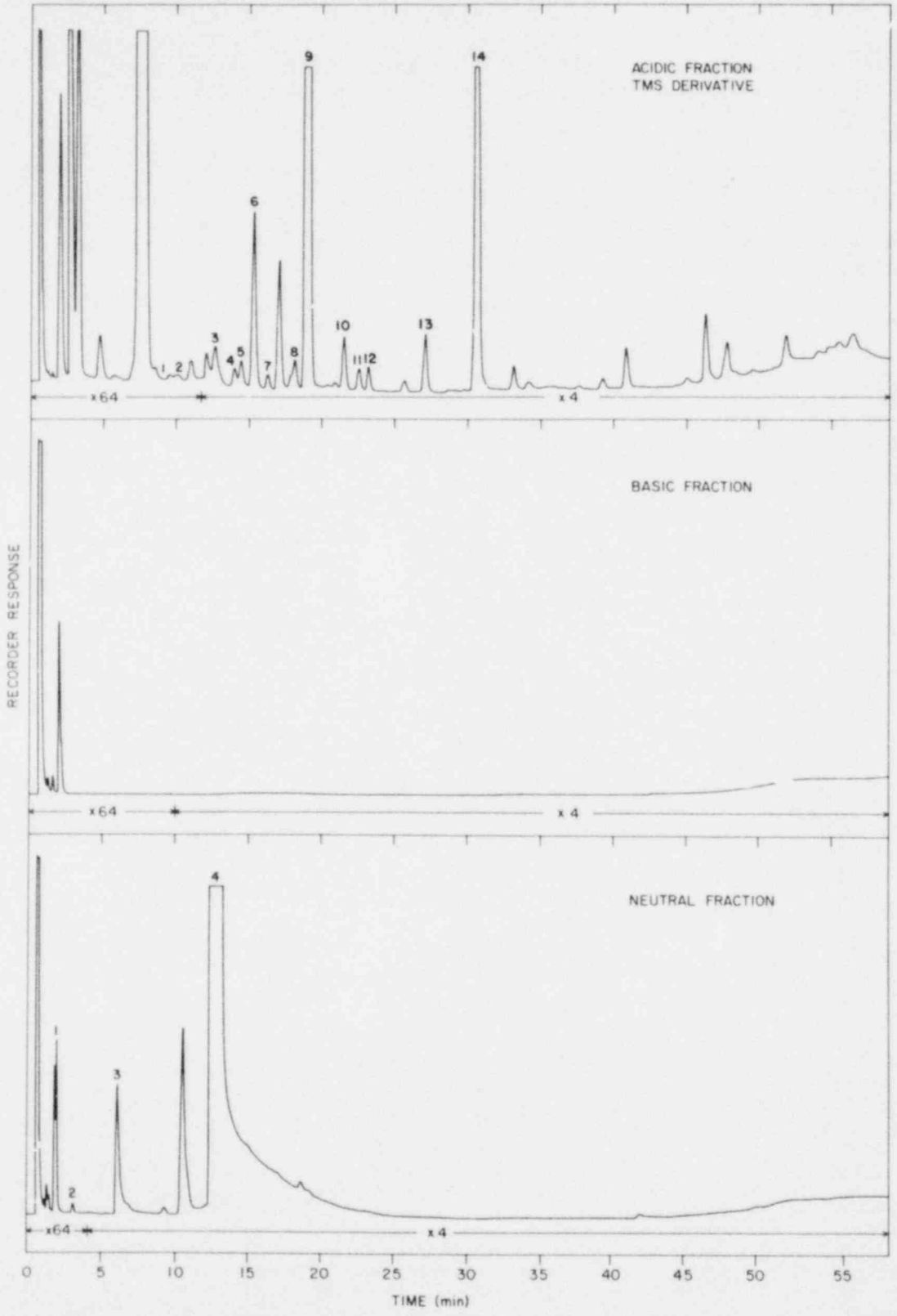

Figure 7. Gas chromatogram of methylene chloride extract of Maxey Flats trench 33L4 water sample.

Table 15

Concentration of Dissolved Organic Compounds Identified in Trench 33L-18 Water Sample from Maxey Flats, Kentucky, Disposal Site[a]

Peak Number	Compound	Concentration mg/l
Neutral Fraction:		
1	p-Dioxane	N.Q.[b]
2	Toluene	<0.12
3	Tributyl phosphate	N.Q.

[a] Key to Figure 8.

[b] Not quantified.

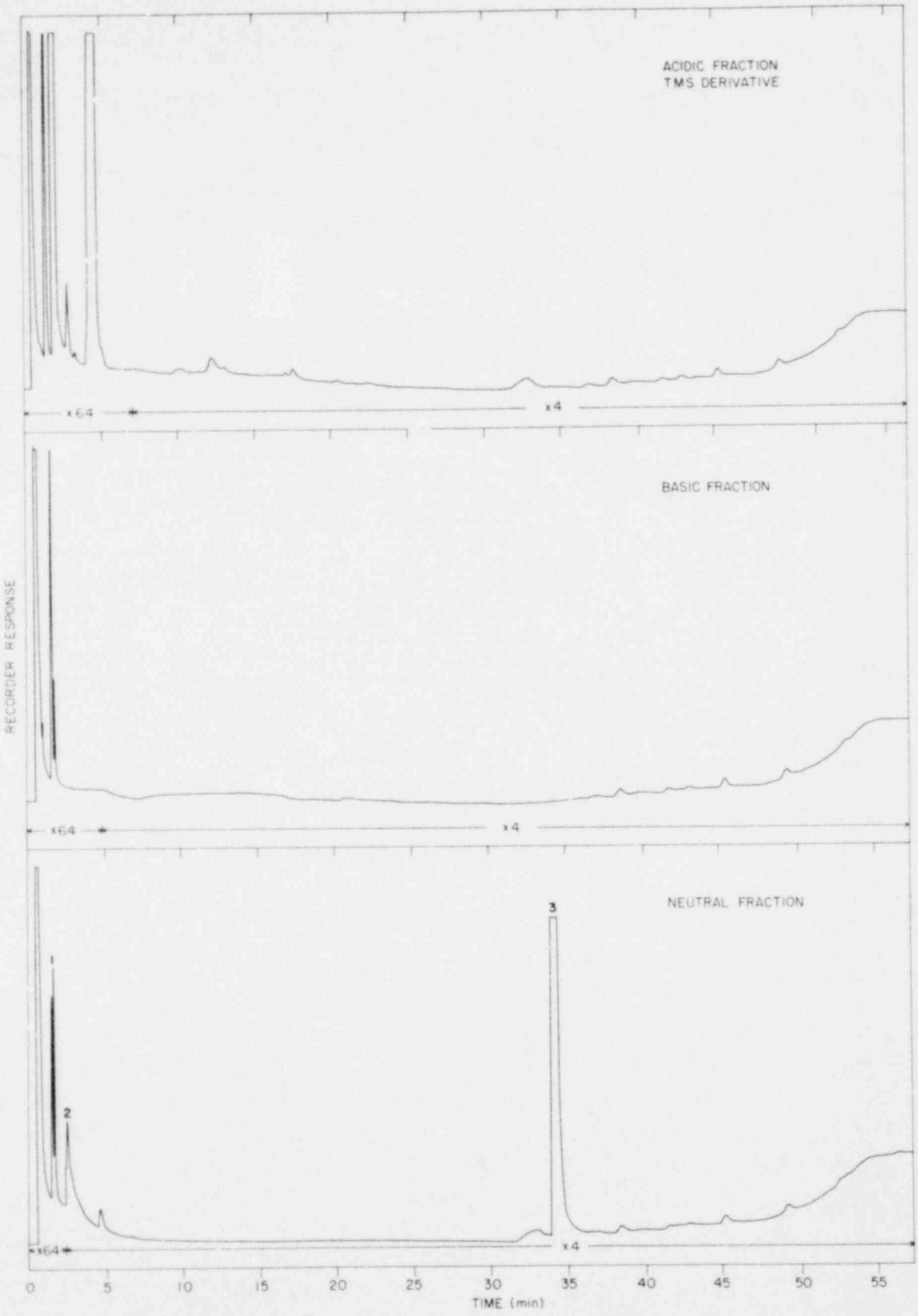

Figure 8. Gas chromatogram of methylene chloride extract of Maxey Flats trench 33L18 water sample.

Table 16

Concentration of Dissolved Organic Compounds Identified in Well UB1 Water Sample from Maxey Flats, Kentucky, Disposal Site[a]

Peak Number	Compound	Concentration mg/l
Acidic Fraction:		
1	2-Methyl butyric acid	0.84
2	2-Methyl pentanoic acid[b]	0.73
3	3-Methyl pentanoic acid	0.16
4	Phenol	0.31
5	Hexanoic acid	1.1
6	2-Methyl hexanoic acid	0.74
7	Cresol (isomer)	0.39
8	Cresol (isomer)	0.38
9	2-Ethyl hexanoic acid	1.6
10	Benzoic acid	0.40
11	Octanoic acid	0.38
12	Phenyl acetic acid	0.44
13	Toluic acid (isomer)	0.13
14	Toluic acid (isomer)	0.28
15	Phenyl propionic acid	3.8
16	Phenyl hexanoic acid	N.Q.[c]
Neutral Fraction:		
1	p-Dioxane	N.Q.
2	Toluene	2.7
3	Xylene	0.12
4	Naphthalene	0.09
5	α-Terpineol	0.16

[a] Key to Figure 9.

[b] Quantified using 3-Methyl pentanoic acid standard.

[c] Not quantified.

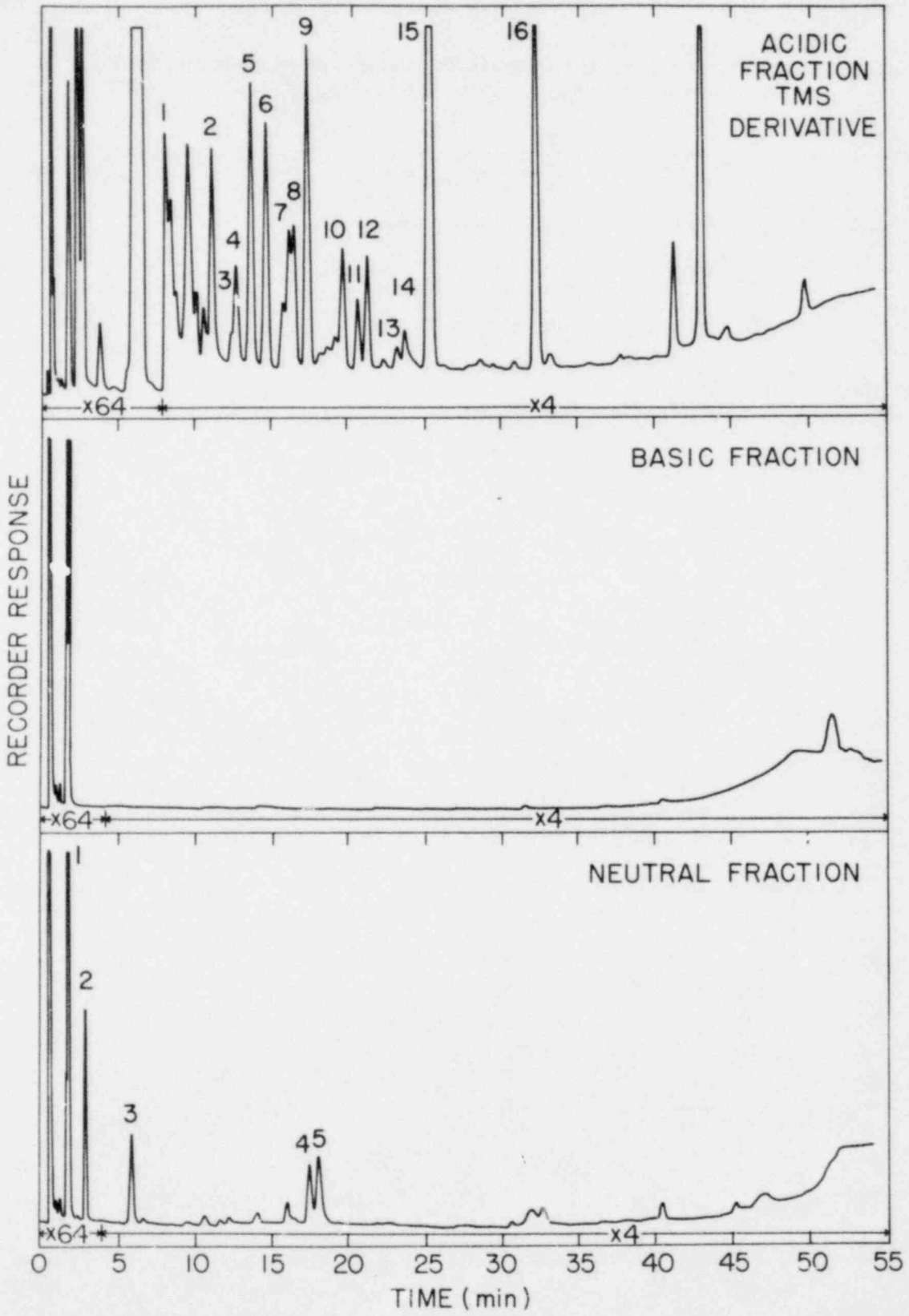

Figure 9. Gas chromatogram of methylene chloride extract of Maxey Flats well UB1 water sample.

Table 17

Concentration of Dissolved Organic Compounds Identified in Well UB1-A Water Sample from Maxey Flats, Kentucky, Disposal Site[a]

Peak Number	Compound	Concentration mg/l
Neutral Fraction		
1	Dibutyl phthalate	0.02
2	Triphenyl phosphate	N.Q.[b]

[a] Key to Figure 10.

[b] Not quantified.

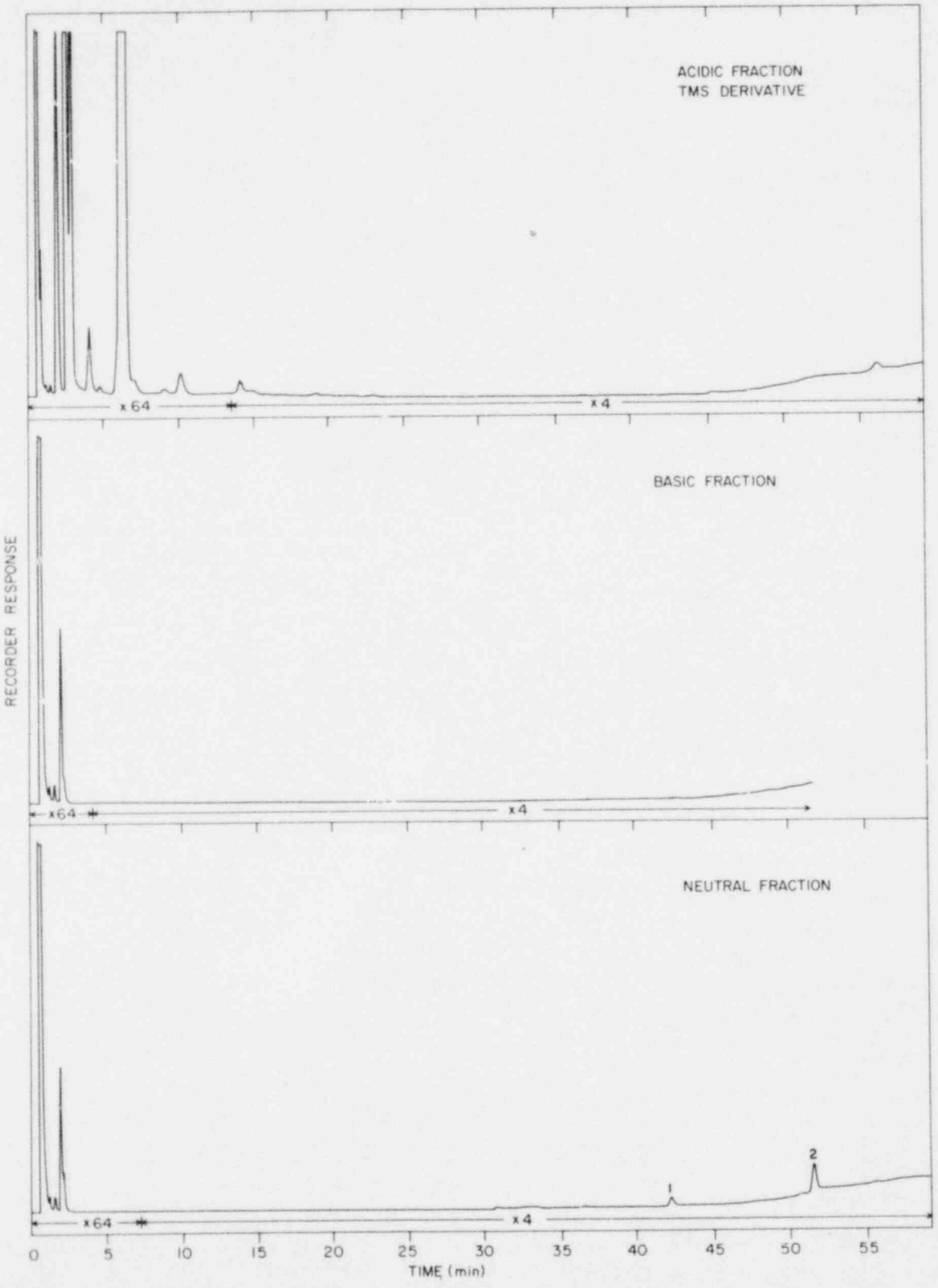

Figure 10. Gas chromatogram of methylene chloride extract of Maxey Flats well UB1A water sample.

V. MICROBIOLOGY (A. J. Francis, S. Dobbs)

Enumeration of Bacteria in Maxey Flats Samples

Water samples collected anoxically from trench 19S and well UB1-A at the Maxey Flats, Kentucky disposal site during May 1978 were analyzed for aerobic and anerobic bacteria, sulfate-reducers, denitrifiers, and methanogens. The bacterial populations of the water samples were determined within 24 hours after collection. Total aerobic and anaerobic bacteria were determined by the pour-plate technique as described previously.[2]

Denitrifying bacteria were determined by the most-probably-number (MPN) technique using nitrate broth as described by Focht and Joseph.[8] The denitrifiers are responsible for the reduction of nitrate and nitrite in the presence of an adequate supply of available organic compounds under anaerobic conditions. The end products of biological denitrification are N_2O and N_2.

Sulfate-reducing bacteria were determined by the MPN technique using pre-reduced-anaerobically-sterilized (PRAS)[9] sulfate API broth (Difco, Detroit, Mich.) prepared in 9 ml volumes in 20 ml serum bottles. Inoculations and dilutions were carried out simultaneously as described in the Difco technical information supplement No. 0233. Vials were incubated at 28°C for 1 to 3 weeks and examined daily for blackening of the medium. Sulfate-reducing bacteria convert the sulfate to sulfide which reacts with ferrous ion and gives the black color. These bacteria are active in the corrosion of iron and aluminum alloys, desulfurization of oil and deposition of mineral sulfides. An anerobic environment with hydrogen or an adequate supply of organic materials is required for efficient reduction of sulfate.

Complex organic materials in soils can be degraded by microorganisms to simple organic acids, alcohols, aldehydes, ketones, esters, and gases such as H_2, H_2S, CO_2, and CH_4. In anaerobic environments the methane-producing bacteria are the terminal organisms in the microbial food chain. Organic acids, alcohols, H_2, and possibly other simple organic compounds serve as energy sources for them. Methanogenic bacteria were determined by the MPN technique by measuring the production of methane in a PRAS modified medium.[10,11] The composition of the medium used in this study is given in Table 18. Inoculations and dilutions in 9 ml of media in aluminum seal tubes (Bellco Glass Co., Vineland, N.J.) fitted

with butyl-rubber septum-lip stoppers[10] were carried out in the same manner as described for sulfate-reducing bacteria. The inoculated media was incubated at 28°C in an atmosphere of 80% H_2 and 20% CO_2. After 4 weeks incubation, the presence of methane in the head space was determined by gas chromatography. A Perkin-Elmer model 3920 gas chromatograph equipped with a flame ionization detector and fitted with 1/8" x 12' stainless steel column packed with Porapak R (mesh 80/100) was used. The operating temperatures were: injector, 150°C; column, 60°C and detector, 250°C.

The population distribution of aerobic and anerobic bacteria, denitrifiers, sulfate-reducers, and methanogens in the trench water and well water samples are given in Table 19. The number of aerobic and anaerobic bacteria expressed as colony forming units (CFU) is within the population range previously determined in water samples from Maxey Flats, Kentucky.[12] The denitrifier populations are much higher than the sulfate-reducers and methanogens.

Studies by Husain, et. al.,[13] have shown that radioactive gaseous compounds such as CH_3T, HTO, HT, other tritiated hydrocarbons, ^{85}Kr, ^{222}Rn, $^{14}CO_2$, $^{14}CH_4$, and other ^{14}C-hydrocarbons have been detected coming from burial trenches at West Valley, N.Y. Of these, tritiated methane is one of the most abundant. Experiments are underway to determine the rate of biological production of methane containing ^{14}C and ^{3}H activity as this may be one of the major pathways of migration of tritium and carbon-14 compounds from trenches.

Identification of Bacteria

Based on differences in colony morphology, several colonies of bacteria were isolated from the aerobic and anerobic agar plates from Maxey Flats and West Valley samples. Tentative identifications of some of the isolates were made with the aid of Bergey"s Manual of Determinative Bacteriology,[14] (according to Willis,[15] Holdeman, and Moore,[9]) descriptive keys included with the BBL-Minitek differentiation sets, and the Roche Oxi/ferm and Enterotubes. The bacteria identified were Bacillus sp, Pseudomanas sp, Citrobacter sp, and Clostridium sp. Several aerobic gram negative isolates with different biochemical properties were present but not identified. The radionuclides and the organic compounds present in the trench water may be acting as mutagenic agents on these bacteria. Isolates 26E1, 26E5, 32E2, and 32E3 were identified as Bacillus sp, 26E2, 26E3,

26E4, 32E6, 32E100, 2E1, 2E2, and 2E3 as Pseudomonas sp, and 32E101 as Citrobacter sp (Table 20). The strict anaerobes listed in Table 21 were identified as Clostridium sp.

Effect of Radionuclides on Trench Water Bacteria

The radioactivity of the waste in the trenches is several orders of magnitude higher than the levels of leached activity detected in the trench water. In addition to radionuclides, a variety of low molecular weight organic acids and alcohols are present in the leachates. The presence of these organic compounds is primarily due to the microbial decomposition of complex organic materials under anaerobic conditions. Although aerobic and anaerobic bacteria have been detected in the water samples and have been shown to be metabolically active,[2] it is not known whether these bacteria can grow in the presence of higher levels of radioactivity. Therefore it is important to determine the threshold level of radioactivity beyond which the trench water bacteria can not survive or contribute to the degradation of the buried wastes. For this purpose, a mixture of radionuclides consisting of ^{60}Co, $^{134,137}Cs$, and ^{85}Sr was prepared in 0.5M HCl and added to growth media to give final activity concentrations of 2.6×10^2 pCi/ml, 2.7×10^3 pCi/ml, 2.7×10^4 pCi/ml and 2.7×10^5 pCi/ml. Uninoculated spiked media were acidified with 10 ml of 6M HCl and were standardized by gamma ray analyses using a Ge(Li) detector and multichannel analyzer system. The levels of each isotope added to the bacterial growth media are shown in Table 22. One milliliter of a 4-day old mixed culture of bacteria from trench 32 at Maxey Flats, grown in filter sterilized trench leachate, was used to inoculate 50 ml of medium in 300 ml nephlo flasks. The medium consisted of NH_4NO_3, 0.5g; $MgSO_4 \cdot 7H_2O$, 0.2g; NaCl, 0.2g; $CaCl_2 \cdot 2H_2O$ 0.025g; $FeSO_4 \cdot 7H_2O$, 0.005g; $(NH_4)_2SO_4$, 0.4g; K_2HPO_4, 4.8g; KH_2PO_4, 1.2g; dextrose, 5.0g; yeast extract, 2.5g, and distilled H_2O, 1000 ml. The growth of bacteria was monitored by measuring the optical density at 525 nm in a Spectronic-20 spectrophotometer.

The effect of a mixture of the radionuclides on the growth of a mixed culture bacteria isolated from trench 32 at Maxey Flats is shown in Figure 11. There is no signif ant difference or effect on the growth of bacteria between the control, containing no radionuclides, and the media, containing 2.6×10^2 and 2.7×10^3 pCi/ml of radioactivity. The levels of radionuclides added to these

bacterial growth media were of the same order of magnitude as those radionuclides found in Maxey Flats trench waters.[12] At a concentration of 2.7×10^4 pCi/ml the growth of bacteria was inhibited and two distinct growth curves were observed. This is probably due to selection of radio-resistant strains or mutants of bacteria. However, growth of bacteria was completely inhibited at 2.7×10^5 pCi/ml of radioactivity.

Table 18

Composition of Media for Culturing Methanogens[1,9]

Component	Amount
KH_2PO_4	0.75 g
K_2HPO_4	1.45 g
NH_4Cl	0.9 g
$MgCl_2 \cdot 6H_2O$	0.2 g
Na_2CO_3	2.0 g
$Na_2S \cdot 9H_2O$	0.5 g
L-Cysteine hydrochloride	0.5 g
Trypticase peptone	2.0 g
Yeast extract	2.0 g
Sodium formate	2.0 g
Sodium acetate	2.0 g
Trace mineral solution[a]	9 ml
Resazurin solution (0.1%)	1 ml
Distilled H_2O	1,000 ml

[a] Composition of trace mineral solution (per liter distilled water adjusted to pH 7.0 with KOH): nitrilotriacetic acid, 4.5g; $FeCl_2 \cdot 4H_2O$, 0.4g; $MnCl_2 \cdot 4H_2O$, 0.1g; $CoCl_2 \cdot 6H_2O$, 0.17g; $ZnCl_2$, 0.1g; $CaCl_2$, 0.02g; H_3BO_3, 0.019g; and $Na_2MoO_4 \cdot 2H_2O$, 0.01g.

Table 19

Enumeration of Bacteria in Water Samples Taken from Maxey Flats, Kentucky Disposal Site, May 1978

Sample	Aerobes (CFU/ml)	Anaerobes (CFU/ml)	Denitrifiers (MPN/ml)	Sulfate-reducers (MPN/ml)	Methanogens (MPN/ml)
Trench 19S	2.2×10^2	3.2×10^2	3.3×10^1	4.0×10^0	4.9×10^0
Well UB1-A	3.4×10^3	1.0×10^1	4.6×10^2	ND[a]	1.0×10^0

[a] Non detected.

Table 20

Characteristics of Bacteria Isolated from Trench Water Samples Taken from Maxey Flats, Kentucky, Disposal Site

Characteristic	Isolate Number															
	Trench 26						Trench 32							Trench 2		
	26E1	26E2	26E3	26E4	26E5	26E6	32E1	32E2	32E3	32E5	32E6	32E100	32E101	2E1	2E2	2E3
Micromorphology:																
Gram stain	+	-	-	-	+	-	+	+	+	-	-	-	-	-	-	-
Cell morphology[a]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Spores	+	ND	ND	ND	+	ND	+	+	+	ND	ND	ND	ND	ND	ND	ND
Motility	-	+	-	-	-	-	-	+	+	-	+	+	+	-	+	-
Biochemical reactions:																
Oxidose	+	+	+	+	-	-	+	+	+	-	+	+	-	+	+	+
Citrate	+	-	+	+	-	-	+	+	-	-	+	+	+	+	+	+
Nitrates reduced[b]	den	den	den	den	-	-	den	den	den	-	-	+	+	+	+	+
Methyl red	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Dextrose	-	aer[d]	aer	aer	+	-	ND	-	-	-	-	+	+	aer	+	+
Maltose	-	-	+	+	+	-	+	-	-	-	-	+	ND	-	+	+
[illegible]3	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Indole	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+
Amylase	+	+	+	+	+	-	+	-	-	-	+	+	-	-	+	+
Lysine decarboxylase	ND[c]	-	-	-	-	-	ND	ND	-	-	-	+	-	-	+	+
Gelatinase	-	-	-	-	+	-	+	-	-	-	-	+	-	-	+	+

(a) R, rods

(b) den, denitrified

(c) ND, not determined

(d) aer, aerobic degradation

Table 21

Biochemical Reactions of Strictly Anaerobic Bacteria Isolated from Trench Water Samples Taken from Maxey Flats, Kentucky, and West Valley, New York, Disposal Sites[a]

	Isolate Number													
	Maxey Flats, Kentucky							West Valley, New York						
	Trench 26		Trench 32		Trench 19S			Trench 3				Trench 8		
Test	26-5	26-9	32-3	32E7	19S-11	19S-13	19S-14	35-7	35E2	35-10	35E3	38-4	38-5	38-6
Dextrose	-	-	-	+	-	+	+	+	+	-	-	-	-	-
Maltose	-	-	-	-	-	+	+	+	-	-	-	-	-	-
Xylose	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Lactose	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Nitrates reduced	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Esculin	-	-	+	-	-	-	-	+	-	-	-	-	-	-
Glycerol	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Cooked meat media[b]	D,B	D	D	d	D	d,g	o	d	d	D,B	D	D,B	B	D

[a] All strains are spore forming rods; will not grow aerobically.

[b] Reactions on cooked meat media: D, digestion; d, slow digestion; g, gas; B, blackening; o, no reaction.

Table 22

Levels of Radionuclides Added to Bacterial Growth Media

Isotope	Activity (pCi/ml)			
^{60}Co	1.1×10^{2}	1.0×10^{3}	1.1×10^{4}	1.1×10^{5}
^{85}Sr	8.9×10^{0}	1.3×10^{2}	1.4×10^{3}	1.4×10^{4}
^{134}Cs	3.8×10^{1}	3.9×10^{2}	3.4×10^{3}	3.4×10^{4}
^{137}Cs	1.0×10^{2}	1.2×10^{3}	1.1×10^{4}	1.1×10^{5}
Total	2.6×10^{2}	2.7×10^{3}	2.7×10^{4}	2.7×10^{5}

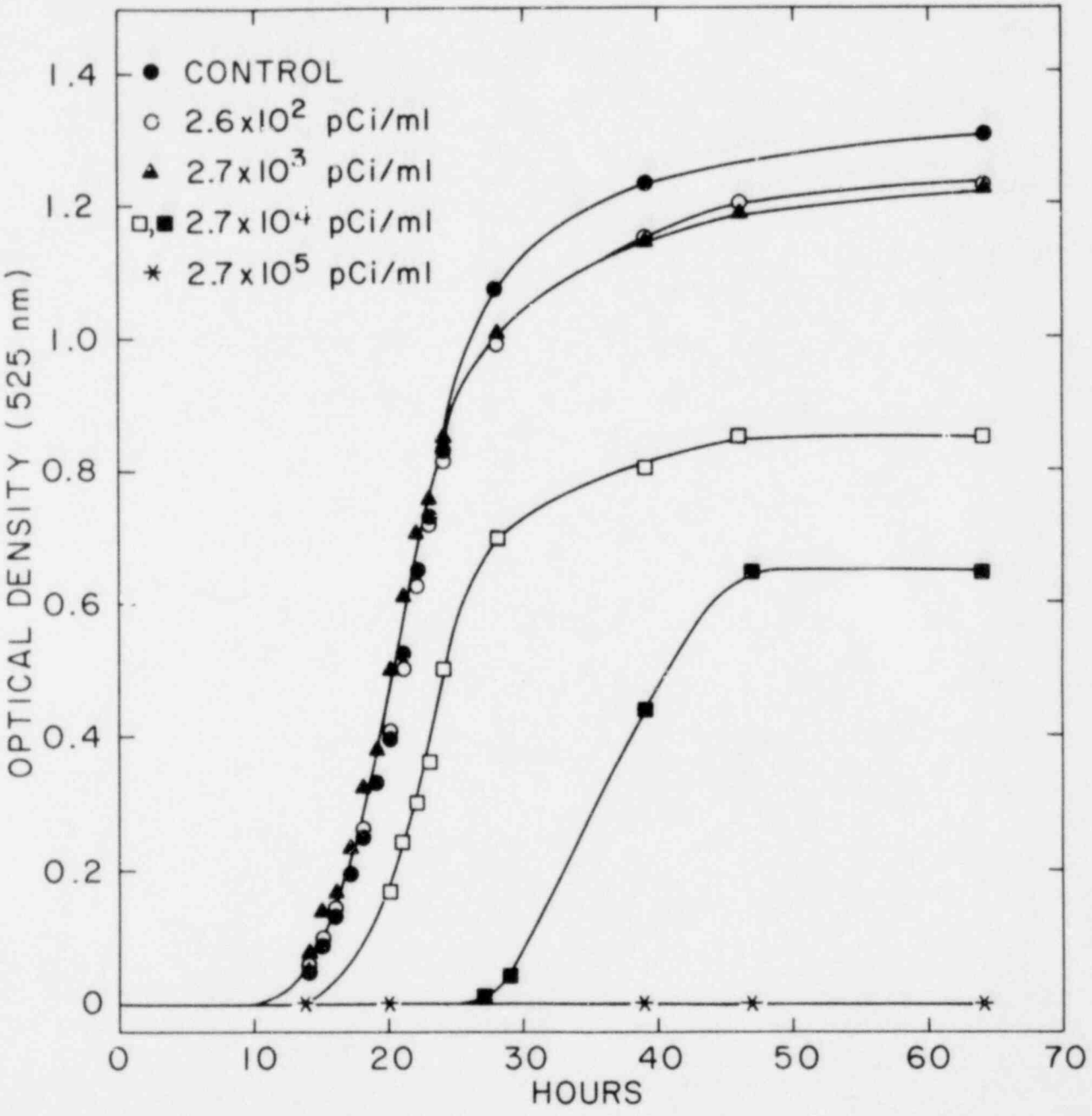

Figure 11. Effect of ^{60}Co, ^{85}Sr, and $^{134,137}Cs$ on growth of mixed culture bacteria from trench 32 at the Maxey Flats, Kentucky, disposal site.

VI. RADIOCHEMICAL ANALYSIS (G.G. Galdi, J. Clinton, R.F. Pietrzak, A.J. Weiss)

Suspended Particulates - West Valley, New York, Trench Water

The concentration of dissolved radionuclides identified in trench water samples taken from West Valley, New York, November 1977 were reported previously.[1] The 0.45 micron membrane filters containing suspended particulates filtered from the trench water samples were dried over silica gel, weighed, dissolved in nitric acid, and counted with a 2 keV resolution Ge(Li) detector. Radionuclide identifications were made on the basis of gamma ray energies and relative peak heights of nuclides emitting more than one gamma. Aliquots of the nitric acid solution were analyzed for strontium-90 and plutonium isotopes as described previously.[1]

The concentration of radionuclides exclusive of the uranium and thorium decay chains measured in the suspended particulates of water samples from trenches 2, 3, 4, 5, 8, and 9 taken from West Valley, November 1977 are given in Tables 23 and 24. Table 23 gives the activities in terms of picocuries per liter of filtered trench water, and Table 24 gives the activities in terms of picocuries per milligram of suspended materials. Gamma rays associated with the members of the uranium and thorium decay chains were examined according to the scheme presented by Smith and Wollenberg.[16] Radium-226 is the only member of these two series present in a significant amount and only in suspended material in trench 5. The concentration of radium-226 in the suspended particulate in trench 5 is 5.8 E0 $\pm$ 28% pCi/mg.

Well UB1 - Maxey Flats, October 1977

The concentration of radionuclides present in the contaminated water encountered while drilling well UB1 are shown in Table 25. Gross alpha, gross beta, and tritium were measured in the sample that was analyzed for organics. Strontium-90, plutonium isotopes, and the Ge(Li) gamma scan were determined from a filtered sample of water from well UB1 (taken a week earlier than the above sample) that was acidified with nitric acid to keep the radionuclides in solution.

Trench Water - Maxey Flats, July 1977

The concentration of dissolved radionuclides measured in water samples from trenches 2, 26, and 32 taken from Maxey Flats, Kentucky, July 1977 are given in Table 26. The kinds and amounts of radionuclides measured in these samples are similar to those obtained in water samples from these trenches collected in

September 1976.[17] The concentrations are within a factor of 2 for all measurements except in trench 26 where ^{238}Pu is approximately four times higher than in 1976, and in trench 32 where tritium is 11 times higher and plutonium isotopes are approximately 30 times higher.

Trench Water - Maxey Flats, May 1978

The concentration of dissolved radionuclides measured in water samples from trenches 19S, 27, 33L-4, and 33L-18 and from well UB1-A collected in May 1978 are given in Table 27. Gross alpha, gross beta, tritium, and ^{90}Sr values measured in trenches 19S, 27, and 33L-4 are comparable to previous values reported for these trenches.[17] However, the plutonium isotopes are generally lower than measured before. There is also a decrease in concentration of ^{60}Co and ^{137}Cs in trench 27 water.

Gamma rays associated with the members of the uranium and thorium decay chains were examined and identified in trenches 27, 33L-4, and 33L-18. Gamma ray peaks in the spectra uniquely associated with specific members of the decay chain and having a large branching ratio were used to calculate the concentrations reported in Table 28. ^{226}Ra, ^{214}Pb, and ^{214}Bi of the ^{238}U series are present in trench 27 water; ^{212}Bi and ^{208}Tl of the ^{232}Th series are present in trench 33L-18 water.

Table 23

Concentration of Radionuclides in Suspended Particulates in Trench Water Samples Taken from West Valley, New York, Disposal Site, November 1977[a]

Radionuclide	Trench 2	Trench 3[b]	Trench 4	Trench 5[c]	Trench 8	Trench 9[d]
^{90}Sr[e]	2.21 E2 (10)	4.55 E3 (10)	4.85 E4 (10)	2.01 E3 (10)	4.09 E1 (120)	3.28 E2 (10)
^{238}Pu[e]	1.04 E1 (10)	6.26 E1 (10)	2.66 E1 (10)	2.67 E1 (10)	7.86 E4 (10)	5.18 E2 (10)
$^{239, 240}Pu$[e]	2.25 E1 (10)	2.07 E2 (10)	5.67 E1 (10)	2.98 E1 (10)	1.85 E2 (10)	4.50 E0 (10)
^{241}Am	8.8 E0 (18)	1.30 E2 (7)	3.3 E1 (16)	2.2 E1 (10)	1.71 E2 (2)	4.4 E1 (4)
^{134}Cs	ND	ND	ND	4.76 E1 (5)	2.0 E0 (41)	4.0 E0 (33)
^{137}Cs	1.10 E2 (3)	9.36 E2 (2)	2.3 E1 (10)	1.82 E3 (0.6)	1.53 E2 (3)	7.4 E1 (4)
^{60}Co	7.8 E0 (25)	7.88 E2 (1)	2.5 E1 (8)	3.1 E1 (87)	2.1 E1 (11)	6.2 E1 (6)
^{40}K	3.7 E1 (55)	2.9 E1 (66)	3.3 E1 (57)	4.2 E0 (44)	2.6 E0 (67)	2.6 E1 (46)

(a) Radionuclide concentration of the suspended particulates given in pCi/l of filtered trench water. Number in parenthesis = 2σ% counting uncertainty.
(b) A gamma ray at 122 keV in trench 3 particulate is tentatively identified as ^{57}Co, 4.8 E0 (67) pCi/l.
(c) Gamma rays at 81 keV and 356 keV in trench 5 particulate are tentatively identified as ^{133}Ba, 7.4 E0 (39) pCi/l.
(d) Gamma rays at 122 keV and 356 keV in trench 9 particulate are tentatively identified as ^{57}Co, 2.1 E0 (48) pCi/l and ^{133}Ba, 4.5 E0 (33) pCi/l respectively.
(e) Analysis performed by LFE Laboratories, Richmond, California.

Table 24

Concentration of Radionuclides in Suspended Particulates in Trench Water Samples Taken from West Valley, New York, Disposal Site, November 1977[a]

Radionuclides	Trench 2	Trench 3[b]	Trench 4	Trench 5[c,f]	Trench 8	Trench 9[d]
^{90}Sr[e]	7.75 E0 (10)	1.10 E2 (10)	2.17 E3 (10)	5.30 E. (10)	2.19 E0 (120)	1.25 E1 (10)
^{238}Pu[e]	3.67 E1 (10)	1.52 E0 (10)	1.19 E0 (10)	7.05 E1 (10)	4.20 E3 (10)	1.99 E1 (10)
$^{239, 240}Pu$[e]	7.90 E1 (10)	5.02 E0 (10)	2.54 E0 (10)	7.87 E-1 (10)	7.74 E0 (10)	1.73 E-1 (10)
^{241}Am	3.1 E-1 (18)	3.15 E0 (7)	1.46 E0 (16)	5.7 E-1 (10)	9.13 E0 (2)	1.69 E0 (4)
^{134}Cs	ND	ND	ND	1.4 E0 (5)	1.08 E-1 (41)	1.4 E-1 (33)
^{137}Cs	3.85 E0 (3)	2.27 E1 (2)	1.0 E0 (10)	4.78 E1 (0.6)	8.19 E0 (3)	2.83 E0 (4)
^{60}Co	2.7 E-1 (25)	1.91 E1 (2)	1.1 E0 (8)	8.23 E-1 (8)	1.14 E0 (11)	2.44 E0 (6)
^{40}K	1.3 E0 (55)	7.1 E-1 (66)	1.5 E0 (57)	1.10 E-1 (44)	1.37 E-1 (68)	1.0 E0 (46)

(a) Radionuclide concentration of the suspended particulates given in pCi/mg of filtered trench water. Number in parenthesis = 2σ% counting uncertainty.
(b) A gamma ray at 122 keV in trench 3 particulate is tentatively identified as ^{57}Co, 1.2 E-1 (67) pCi/mg.
(c) Gamma rays at 81 keV and 356 keV in trench 5 particulate are tentatively identified as ^{133}Ba, 5.7 E-1 (39) pCi/mg.
(d) Gamma rays at 122 keV and 356 keV in trench 9 particulate are tentatively identified as ^{57}Co, 8.2 E-2 (48) pCi/mg and ^{133}Ba, 1.7 E-1 (33) pCi/mg respectively.
(e) Analysis performed by LFE Laboratories, Richmond, California.
(f) Radium-226 identified in trench 5 particulate = 5.8 E0(28)pCi/mg.

Table 25

Concentration of Dissolved Radionuclides in Well UB1
taken from Maxey Flats, Kentucky, Disposal Site, October 1977

Radionuclide	Collection Date	Concentration (pCi/l)[a]
Gross Alpha	10/21/77	2.64 E3 (17)
Gross Beta	10/21/77	2.37 E5 (1.7)
Tritium	10/21/77	4.26 E8 (<1)
^{90}Sr[c]	10/13/77	7.10 E4 (10)
^{238}Pu[c]	10/13/77	3.32 E1 (10)
$^{239,240}Pu$[c]	10/13/77	4.2 E-1 (60)[b]
^{60}Co	10/13/77	4.68 E3 (2.3)

(a) Number in parenthesis = 2σ% counting uncertainty.

(b) Counting uncertainty = 1σ.

(c) Analysis performed by LFE Laboratories, Richmond, California.

Table 26

Concentration of Dissolved Radionuclides in Trench Water Taken from Maxey Flats, Kentucky, Disposal Site, July 1977[a]

Radionuclide[b]	Trench 2	Trench 26	Trench 32
Gross Alpha	6.73 E3 (8.5)	2.71 E4 (4.0)	3.07 E4 (3.9)
Gross Beta	2.38 E4 (5.5)	1.18 E5 (1.2)	1.79 E6 (<1)
Tritium	2.09 E7 (<1)	1.28 E8 (<1)	2.27 E9 (<1)
^{90}Sr	4.03 E3 (5.2)	3.08 E4 (1.6)	5.63 E5 (<1)
^{238}Pu[b]	9.38 E3 (10)	1.26 E5 (10)	1.14 E5 (10)
$^{239, 240}Pu$[b]	2.75 E2 (10)	3.51 E3 (10)	2.92 E3 (10)
^{241}Am	2.85 E3 (8.9)	N.D.[c]	N.D.
^{60}Co	1.00 E4 (4.5)	1.37 E3 (14)	3.49 E3 (8.1)
^{137}Cs	N.D.	5.33 E3 (5.7)	4.78 E3 (5.5)

[a] Radionuclide concentrations given in picocuries/liter. Number in parentheses = 2σ% counting uncertainty.

[b] Analysis performed by LFE Laboratories, Richmond, California.

[c] Not detected.

Table 27

Concentration of Dissolved Radionuclides in Trench Water Taken from Maxey Flats, Kentucky, Disposal Site, May 1978[a]

Radionuclide	Trench 19S	Well UB1-A	Trench 27	Trench 33L-4[b]	Trench 33L-18
Gross Alpha	1.67 E5 (1.7)	<10	5.74 E4 (11)	4.92 E3 (11)	5.86 E5 (3.0)
Gross Beta	6.40 E5 (2.0)	3.10 E2 (30)	3.97 E5 (2.6)	3.69 E4 (8.8)	2.26 E5 (3.5)
Tritium	6.80 E7 (<1)	5.80 E6 (<1)	5.88 E8 (<1)	2.87 E7 (<1)	4.56 E7 (<1)
^{90}Sr[c]	2.92 E5 (10)	6.25 E1 (10)	2.12 E5 (10)	1.74 E4 (10)	3.39 E4 (10)
^{238}Pu[c]	2.14 E5 (10)	1.42 E1 (16)	4.13 E3 (10)	4.21 E2 (10)	8.03 E3 (12)
$^{239, 240}Pu$[c]	8.43 E2 (10)	0.54 E0 (114)	6.70 E2 (10)	6.57 E3 (10)	2.37 E3 (20)
^{241}Am	1.51 E3 (17)	N.D.	1.41 E3 (17)	N.D.	3.89 E3 (5.8)
^{60}Co	2.5 E3 (11)	2.5 E2 (13)	1.3 E3 (21)	3.6 E1 (64)	5.5 E3 (6.6)
^{134}Cs	N.D.	N.D.	N.D.	N.D.	1.2 E3 (14)
^{137}Cs	1.04 E4 (3.8)	N.D.	7.97 E3 (4.6)	2.1 E2 (66)	2.18 E4 (2.4)

[a] Radionuclide concentration given in picocuries/liter. Number in parentheses = 2σ% counting uncertainty.

[b] A gamma ray at 1274 kev was assigned ^{22}Na with a concentration = 8.8 ± 22% pCi/l.

[c] Analysis performed by LFE Laboratories, Richmond, California.

Table 28

Uranium and Thorium Decay Series Members Identified in Trench Water Samples Taken from Maxey Flats, Kentucky, Disposal Site, May 1978

Gamma Ray (keV)	Series	Radionuclide	Concentration - pCi/l[a]		
			Trench 27	Trench 33L-4	Trench 33L-18
186	^{238}U	^{226}Ra	4.8 E3 (82)	----	----
352	^{238}U	^{214}Pb	1.4 E3 (24)	----	----
609	^{238}U	^{214}Bi	1.4 E3 (19)	----	----
210	^{232}Th	^{228}Ac	7.7 E3 (34)	----	----
583	^{232}Th	^{208}Tl	----	----	5.2 E3 (14)
727	^{232}Th	^{212}Bi	----	----	8.8 E3 (23)

(a) Number in parenthesis = 2σ% counting uncertainty.

VII. DISCUSSION

The organic compounds identified in well UB1 are of particular interest. A comparison of Table 16 with Table 13 shows that every organic compound, except toluic acid, identified in well UB1 is also present in trench 32. A majority of organic compounds identified in well UB1 are also present in trench 19S (Table 10). The location of well UB1, relative to trench 19S and trench 32 is shown in Figure 1. There is not enough information to state that leachate from trench 19S and/or leachate from trench 32 migrated to well UB1, or that the source of water in well UB1 is from other trenches. However, there is sufficient evidence to conclude that there was communication between well UB1 and leachate from wastes buried in the trenches at Maxey Flats, Kentucky. This conclusion is supported by the alpha, beta, tritium, ^{90}Sr, ^{60}Co and plutonium isotopes measured in well UB1 water sample (Table 25). Additional information to verify this connection might be obtained by fracturing the cement grout in the well with an explosive charge, thereby allowing the well to recharge, and studying the communication between the well and leachate from neighboring trenches.

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