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Sampling and Analysis of SWSA 6 Trench Leachates and Groundwaters

D. K. Solomon
R. C. Haese
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Environmental Sciences Division
Publication No. 3117

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ENVIRONMENTAL SCIENCES DIVISION

SAMPLING AND ANALYSIS OF SWSA 6 TRENCH LEACHATES AND GROUNDWATERS

D. K. Solomon, R. C. Haese, T. V. Dinsmore,[1] and A. D. Kelmers[1]

Environmental Sciences Division
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[1]Chemical Technology Division

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ABSTRACT

SOLOMON, D. K., R. C. HAESE, T. V. DINSMORE, and A. D. KELMERS. Sampling and analysis of SWSA 6 trench leachates and groundwaters. ORNL/TM-10813. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 88 pp.

This report summarizes the results of groundwater and trench leachate sampling and analysis activities conducted during FY 1986 and FY 1987 in Solid Waste Storage Area (SWSA) 6, a low-level radioactive waste disposal site at Oak Ridge National Laboratory. This work was carried out to obtain concentration data for contaminants [radionuclides, Environmental Protection Agency (EPA) priority pollutant and Superfund site organic compounds, hazardous inorganic metals, and other chemicals] and water quality data that would be applicable to the development of contaminant source terms for use in modeling future site performance and in evaluating remedial action and site closure options. An experimental water sampling and analysis approach was undertaken because the available contaminant inventory information for the site was inadequate for source-term modeling needs. SWSA 6 has operated as a low-level waste site since 1968. A variety of radioactive wastes, both with and without containerization, has been emplaced by shallow-landfill techniques via disposal in trenches and auger holes. Field analyses of both trench leachate and groundwater samples showed values typical of shallow groundwaters in eastern Tennessee for temperature, acidity, dissolved oxygen, redox potential, conductivity, and alkalinity. Chemical analyses of major cations and anions were also typical of groundwaters; major ions were calcium, magnesium, sodium, bicarbonate, sulfate, and chloride. Radiochemical analyses showed that tritium was ubiquitous in both trench leachate and groundwater samples; a maximum value of 340,000 Bq/L was measured in one trench, and over half of the samples had ^{3}H concentrations exceeding 1000 Bq/L. Some trench leachates contained ^{90}Sr (a maximum of 3600 Bq/L was measured), but ^{90}Sr was

low or below detection levels in groundwaters. Low levels of ^{137}Cs were detected in a few leachate samples. Twenty-one EPA priority pollutant organic compounds were detected in both trench leachate and groundwater samples. Several organics were present in both trench leachate and groundwater samples at relatively high concentrations (1-mg/L range): benzene, naphthalene, tetrachloroethylene, toluene, and trichloroethylene. Chloroform, methylene chloride, xylenes, and naphthalene were present in one or more samples at concentrations that exceed the limit for Superfund sites. While additional analyses of priority pollutant organics are required, the information obtained to date suggests that organics at the site could represent a significant environmental concern. Several trenches were sampled over a 15-month period to explore the variation of contaminant concentrations over time. The concentrations measured did not correlate well with expected trench hydrology changes between dry and wet periods. More work is needed to understand the response of contaminants to changes in water flux with time. The total radionuclide activity in four trench leachates was compared with existing site radionuclide inventory data for those trenches; it might be expected that the most contaminated water samples would be obtained from trenches having the highest inventory. Such was not the case, however, and the present results suggest that historic radionuclide inventory data may be of little use in predicting radionuclide source terms, and, therefore, experimental measurements may be necessary to develop defensible source terms. No historic information exists for organics or hazardous inorganic materials, and source terms for these contaminants can be developed only through experimental measurement. Several recommendations for future sampling and analysis work at the site are included in the report.

1. INTRODUCTION

The purpose of this work was to acquire information about the leaching and transport of contaminants [radionuclides, Environmental Protection Agency (EPA) priority pollutant and Superfund site organic compounds, hazardous inorganic metals, and other chemicals] in the wastes emplaced in trenches and auger holes in Solid Waste Storage Area (SWSA) 6. These data can be applied to the development of contaminant source terms. (A source term is a mathematical expression that describes the quantity of a contaminant released as a function of time. In the case of wastes emplaced in trenches and auger holes at SWSA 6, release is considered to be mobilization of the contaminants out of the trench or auger hole via groundwater.) Traditionally, contaminant source terms have been determined based on knowledge of the contaminant inventories in the wastes, along with assumptions, estimates, or measurements of the groundwater flux, solubility of the contaminants in groundwater, etc. Although some inventory data exist for radionuclides in SWSA 6 (Boegly 1984, Boegly et al. 1985), the data do not provide the detailed information required to adequately determine contaminant source terms. Only limited information on the identity or quantity of radionuclides discharged to SWSA 6 was included in the SWSA 6 historic disposal log. Furthermore, other contaminants such as organic compounds and metals are known to be present in some of the wastes in SWSA 6, but no information on such materials was included in the SWSA 6 historic disposal log. Therefore, in the work described in this report, we are undertaking an experimental approach to establish contaminant source term information. This approach involves collecting water samples from as near the waste as is logistically possible and analyzing them for contaminants. Trench leachate has been sampled directly from monitoring wells located inside trenches. However, the installation of monitoring wells directly into auger holes was precluded both by the auger hole construction (concrete cap) and by

the high levels of radioactivity in many auger holes (reportedly up to 5870 Ci in a single auger hole). To gain information about the contaminants in wastes in auger holes, leachate is being collected from nearby groundwater monitoring wells.

Solid low-level radioactive waste (LLW) has been discharged from Oak Ridge National Laboratory (ORNL) into shallow, unlined trenches and unlined auger holes (or, in a few cases, into lined auger holes) in SWSA 6 since 1968. (The terms "trenches" and "auger holes" should be understood to define the mechanism of opening a cavity for waste emplacement in the soil. After the trench or auger hole is backfilled with available soil, it has identity only as a geographic location. Thus, the wastes have essentially been disposed of by shallow-landfill methodology.) SWSA 6 is the currently active LLW disposal facility at ORNL. The operational history and summaries of the information available concerning SWSA 6 are given in Boegly (1984) and Boegly et al. (1985). Information on the inventory and calculated release rates for high-activity LLW in one set of auger holes at SWSA 6 is given in Kelmers and Hightower (1987). Soil information for SWSA 6 is reported in Lietzke and Lee (1986). Preliminary radionuclide sorption data for SWSA 6 soils are reported in Friedman and Kelmers (1987).

The composition of wastes within SWSA 6 trenches is extremely variable both chemically and physically. In addition, waste containerization varies from no containerization to the use of concrete boxes, glass bottles, or steel cans. With the exception of relatively small volumes of transuranic wastes and high-level wastes that are shipped off site for disposal, the SWSA 6 site has received essentially all the LLW generated at ORNL since 1968. LLW from other sites involved with Department of Energy activities has also been accepted at SWSA 6 (Boegly 1984). The majority of trenches and auger holes have been classified as (1) low-activity LLW, (2) high-activity LLW, (3) asbestos, or (4) animal remains (Davis and Solomon 1987). Trenches and auger holes have generally been grouped spatially within SWSA 6 according to these categories.

Because it is not feasible with current budget and manpower resources to sample a statistically significant number of these

trenches and auger holes, a "worst case" approach has been used in this work. The existing SWSA 6 waste inventory was used to select one or two trenches within each major group (1 through 4 above) that, according to the records, contained the highest amounts of radioactivity. For trench groups that existed before the inventory was initiated, one trench was randomly chosen in each group. A similar approach was followed in placing wells adjacent to auger holes.

The mean annual rainfall at the SWSA 6 site is about 132 cm; thus, a considerable flux of water is available for mobilizing contaminants from the bulk waste and transporting dissolved or dispersed contaminants through the environment. Water may enter waste trenches or auger holes directly by infiltrating the trench or auger hole cap, by lateral flow along macropores above the water table, or by lateral flow in the saturated zone when the local water table is above the bottom of the trench or auger hole. [All auger holes are believed to be situated above the local water table. A description of auger hole construction is given in Appendix A of Kelmers and Hightower (1987.)] The principal pathway for the transport of contaminants from SWSA 6 is considered to be the saturated groundwater system, although a significant but unevaluated portion of the source term could be in the unsaturated zone. Individual waste trenches or auger holes, or in some cases groups of closely spaced trenches or auger holes, can be viewed as point sources that deliver contaminants to the groundwater systems.

In this report, we describe trench leachate and groundwater samples taken in SWSA 6 during FY 1986 and FY 1987. The specific objectives of this phase of the work to support source term characterization were the following:

1. to define the chemistry and contaminant concentration of trench leachate,
2. to evaluate seasonal variability in trench leachate chemistry and contaminant concentration, and
3. to define the general character and contamination of groundwater near auger holes.

1.1 TRENCH HYDROLOGY

Unlined waste trenches in SWSA 6 are typically 3 m wide by 15 m long by 4.5 m deep (Davis and Solomon 1987, Davis et al. 1986). Although the trenches were originally placed in the unsaturated zone, standing water has been observed on occasion in many trenches within SWSA 6. Water level data collected by the U.S. Geological Survey from 1975 to 1979 (Webster et al. 1980), along with additional water level data collected by this and other projects in the Environmental Sciences Division from 1985 to 1987, show that trenches can be hydrologically classified according to one of five criteria:

1. inundated (the trench is saturated and the water table elevation adjacent to the trench is approximately equal to the water level elevation observed in monitor wells inside the trench),
2. unsaturated (the water table outside the trench is consistently below the trench bottom and standing water is not observed in the monitor wells),
3. bathtubbing (the water table elevation adjacent to the trench is consistently less than the water level elevation inside the trench but standing water is observed in the trench monitor wells),
4. intermittently inundated (combination of 1 and 2), and
5. intermittently bathtubbing (combination of 2 and 3).

Figure 1 shows that 15% of the trenches in SWSA 6 are estimated to have remained completely unsaturated for the period from 1975 to the present. Only about 1% of the trenches remained continually inundated or were bathtubbing during all of this period. Thus, the majority of trenches (about 84%) in SWSA 6 are estimated to have contained standing water intermittently throughout this period. Water level measurements were made on 14 trench monitoring wells during 1986 and 1987. Only 6 of the 14 trenches monitored contained standing water for more than a 1-month period from 1986 through 1987.

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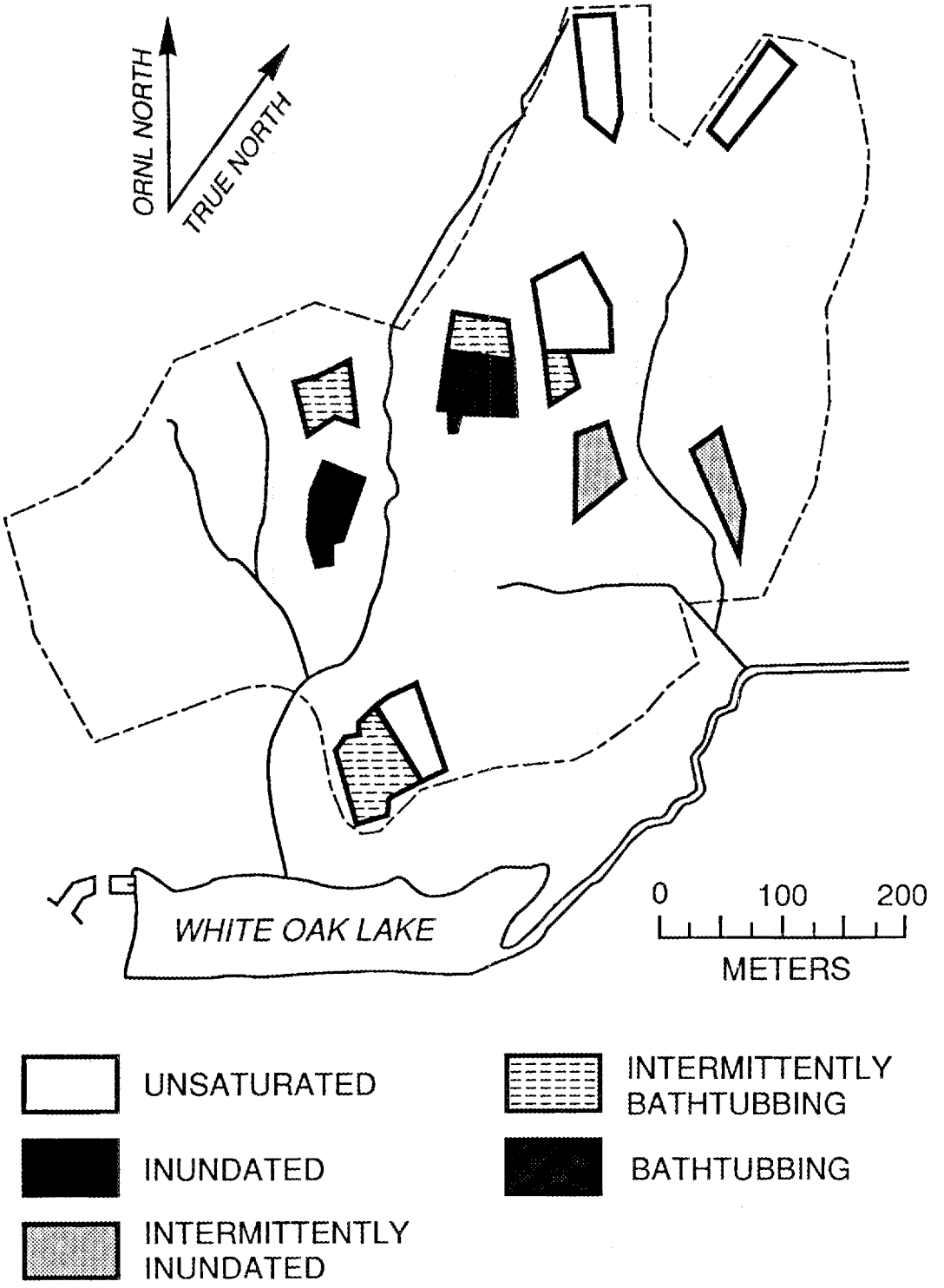

Fig. 1. Hydrologic condition of trenches in SWSA 6.

1.2 AUGER HOLE HYDROLOGY

Auger holes were typically bored to about 0.5 to 1.5 m in diameter and about 6 to 7 m in depth. They were generally constructed in topographically high areas, and the bottoms of the holes were about 2 m above the local water table (Boegly 1984). About 92% of the total radioactivity in SWSA 6 has reportedly been emplaced in auger holes. Most of the auger hole radioactivity is contained in metal parts discharged from the High Flux Isotope Reactor and consists of $^{152,154,155}Eu$, ^{60}Co, and ^{55}Fe, plus lesser amounts of ^{59}Ni and ^{63}Ni (Kelmers and Hightower 1987). Water level data from 1976 to 1987 indicate that auger holes are not inundated by a high water table, but standing water was observed during construction of several auger holes (J. Bolinski, ORNL Operations Division, personal communication, 1986). The existence of a bathtubbing condition has not been explored because monitoring wells do not exist within the auger holes.

2. METHODS

Collection and analysis of waste leachate was conducted during FY 1986 and FY 1987. Analytical methods employed by the Analytical Chemistry Division (ACD) remained constant throughout the study. The accumulation of field analysis data in FY 1986 was time-consuming and difficult due to the use of laboratory equipment that was not specifically designed for field use. (A gasoline-powered generator was used to operate laboratory equipment set up on the tailgate of a pickup truck.) Although the FY 1986 field analyses are considered accurate, the acquisition of a new analytical instrument designed for field use allowed rapid measurement of the field parameters [pH, temperature, dissolved oxygen (DO), etc.]. This instrument allowed use of a new protocol for collecting leachate samples. Thus, field measurement and sample collection techniques during FY 1987 differed slightly from those employed during FY 1986. The analytical methods, as well as the field methods used in FY 1986 and FY 1987, are documented in this report.

2.1 SAMPLE COLLECTION FROM SATURATED PIEZOMETERS

Collection of leachate samples from 17 trench monitoring wells and 5 groundwater monitoring wells was planned. It was not possible to sample all trench monitoring wells as planned because of unsaturated conditions that were continually encountered or because some wells were extremely low yielding and the minimum sample volume of about 2 L could not be obtained. Eight trench wells or five groundwater wells were actually sampled.

Details of individual well construction are given in Table 1. Wells T41, T135, and T163 were constructed prior to FY 1986, and only a limited amount of construction information was available. Most of the remaining trench monitoring wells were constructed of type 304 stainless steel pipe with a stainless steel screen and were installed specifically to sample trench leachates and monitor trench

Table 1. Construction details of SWSA 6 trench leachate and groundwater monitoring wells

Well ID	Construction	Casing type	Casing diameter (cm)	Total depth (m BLS)[a]	Screened interval (m BLS)
T8	Driven	SS[b]	5.1	4.85	3.32-4.85
T41	Augered	PVC[c]	7.6	3.75	Unknown
T92	Augered	PVC	7.6	4.12	2.59-4.12
T135	Augered	PVC	7.6	4.61	Unknown
T163	Augered	PVC	7.6	4.54	Unknown
T219	Driven	SS	5.1	3.62	2.1-3.62
T260-2	Driven	SS	5.1	2.89	1.37-2.89
T257	Driven	SS	5.1	3.60	2.07-3.60
T288	Driven	SS	5.1	4.32	2.80-4.32
T315	Driven	SS	5.1	2.59	1.07-2.59
T391	Driven	SS	5.1	4.42	2.90-4.42
T405	Driven	SS	5.1	3.20	1.68-3.20
T417	Driven	SS	5.1	3.87	2.35-3.87
T444	Driven	SS	5.1	4.05	2.53-4.05
S-11	Augered	PVC	5.1	13.81	9.24-13.81
647	Augered	SS	10.2	10.97	7.92-10.97
648	Augered	SS	10.2	13.72	10.67-13.72
649	Augered	PVC	5.1	11.28	6.71-11.28
650B	Augered	SS	5.1	18.29	15.85-18.29

[a]BLS = below land surface.
[b]SS = stainless steel.
[c]PVC = polyvinyl chloride.

water levels. These wells were cleaned with acetone and distilled water and then driven and/or hydraulically pushed into place. Water table monitoring wells 642, 648, and 650B were constructed using 20.3-cm continuous-flight augers that were steam cleaned prior to use. The wells were cased with schedule 5S, type 304 stainless steel pipe that was steam cleaned and washed in 95% ethyl alcohol prior to installation. Trench well T92 and water table monitoring well S-11 were constructed by augering 15.2 cm-diam holes and were cased with polyvinyl chloride (PVC) slotted screen and riser pipe. The annuli were filled with quartz sand extending approximately 0.6 m above the well screen, followed by a 0.3 m bentonite plug, and were finished with cement grout to the surface. Figure 2 shows the number and location of the monitoring wells.

Samples were collected using either (1) positive displacement, 100% Teflon bladder pumps or (2) peristaltic pumps fitted with Teflon tubing extending down the well and Tygon tubing around the pump head. Bladder pumps were used whenever a sufficient column of water was present in the well. In general, it was possible to use only the bladder pumps in the water table monitoring wells. Water table monitoring wells 648, 649, and 650 were equipped with dedicated bladder pumps.

The bladder pump used on all the remaining wells was washed in 10% HCl and rinsed in deionized water prior to each use. All of the tubing used with the peristaltic pumps was replaced after each sampling to prevent cross contamination of samples. The type of pump used in sampling each well is shown in Table 2. During FY 1986, a minimum of three casing volumes of water were pumped from water table wells prior to sampling. Due to the relatively small quantity of water residing in the saturated zone within trenches, a maximum of 1 and a minimum of zero casing volumes of water were pumped from trench monitoring wells prior to sampling during FY 1986. The ability to make rapid field measurements with a new Surveyor II field instrument (see Sect. 2.3) allowed an improved purging technique to be used in FY 1987. Purge water was pumped through the flow-through cell of the Surveyor II while

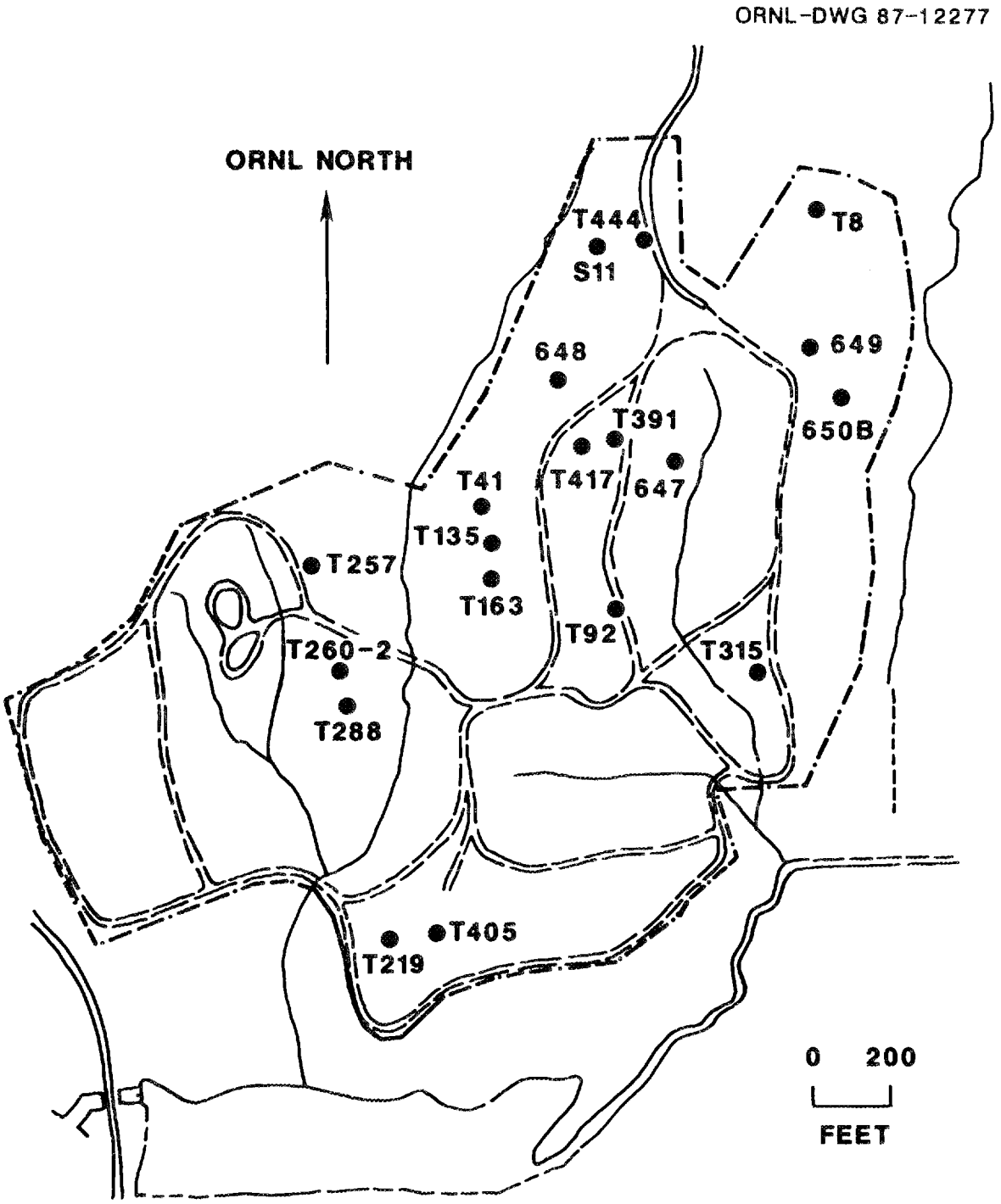

Fig. 2. Locations of trench and groundwater monitoring wells in SWSA 6.

Table 2. Collection of leachate and groundwater samples

Well ID	Sampling date	Pump type	Number of casing volumes removed prior to sampling
T41	3/11/86	Peristaltic	1
T41	12/4/86	Peristaltic	1
T41	3/10/87	Peristaltic	1
T92	4/22/86	Bladder	0
T92	12/4/86	Peristaltic	1
T92	3/10/87	Peristaltic	1
T135	4/13/87	Peristaltic	1
T163	4/21/87	Peristaltic	0.5
T219	1/21/87	Peristaltic	1
T257	12/5/86	Peristaltic	1
T257	1/21/87	Peristaltic	1
T257	3/10/87	Peristaltic	1
T260-2	4/13/87	Peristaltic	1
T288	3/21/86	Bladder	1
T288	12/5/86	Peristaltic	1
T288	3/10/87	Peristaltic	1
S11	3/17/86	Bladder	3
647	7/10/86	Bladder	3
648	1/21/86	Bladder	3
649	3/11/87	Bladder	3
650	3/11/87	Bladder	3

field parameters, including temperature, pH, DO, and conductivity, were monitored. Purge volumes for each sample are listed in Table 2. Purging was continued until one of the three following conditions was met.

1. The measured field parameters (see Sect. 2.3) stabilized. For example,

    - the temperature did not vary by more than 0.2°C in 1 min,
    - the pH did not vary by more than 0.1 units in 1 min,
    - the DO did not vary by more than 1 mg/L in 1 min, and/or
    - the conductivity did not vary by more than 5% from the initial value.

2. The well went dry. (If a well went dry, it was allowed to recover. If sufficient recovery occurred for sampling within 24 h, the well was sampled and the recovery time was recorded in the log. If sufficient recovery did not occur within 24 h, the well was not sampled.)

3. Three standing volumes of water were removed from the well.

Several sample splits were collected from each well for the analyses to be performed by the ACD (see Sect. 2.4). Samples for semivolatile organics were collected in 1-L glass bottles equipped with Teflon stoppers. Samples for volatile organics were collected in 40-mL glass bottles closed with Teflon seals; the bottles were completely filled to eliminate any headspace above the sample. The pumping rate during the collection of volatile organic samples was always less than 100 mL/min to avoid outgassing the sample. Two separate samples were collected for radiochemical analyses. A 1-L filtered (in-line 0.45-µm acrylic polymer filter), untreated sample was collected in a polyethylene bottle, and a second 2-L filtered, acidified (to pH <1 with HNO_3) was collected in a polyethylene bottle. Two separate

samples were also collected for inorganic chemical analyses. A 1-L filtered, untreated sample and a 1-L filtered, acidified sample (to pH <2 with HNO_3) were collected; both were taken in polyethylene bottles. All samples were placed on ice for transport to ACD.

2.2 SAMPLE COLLECTION FROM UNSATURATED LYSIMETERS

It is estimated that more than 90% of the trenches and possibly all of the auger holes are unsaturated for a significant portion of the year. Thus, leachate that develops and is transported under unsaturated conditions may represent a significant portion of the source term. Leachate under unsaturated conditions cannot be sampled using conventional piezometer-type monitoring wells. Commercially available equipment for sampling groundwater under unsaturated conditions was obtained (BAT Envitech, Inc.). This system includes a lysimeter sampling tip that consists of a ceramic filter in a stainless steel case with a 2.54-cm galvanized riser pipe. The filter has a pore size of approximately 2 μm and can extract soil water when sufficient suction is applied. Vacuum is obtained by evacuating 35-mL vials equipped with removable septa. The vials, along with a double-ended septum apparatus, are lowered down the riser pipe. Each sampling tip also has a septum, and a series of weights is used to hydraulically connect the sampling tip to the evacuated vial. Soil water is then sucked through the tip into the sample vial.

The physical nature of the bulk waste is such that considerable uncertainty existed concerning the possibility of achieving a hydraulic connection between the filter tip and the surrounding waste. Further uncertainty existed concerning the physical integrity and strength of the filter tip, stainless steel case, and iron riser pipe. The sampling system was tested by hydraulically pushing the lysimeter sampling tips into trenches 444 and 417. The installation into trench 444 resulted in a bent riser pipe, and the sampling vial could not be lowered to the filter tip. The installation into trench 417 was successful, and about 25 mL of soil water was recovered in a 1-h period.

A minimum sample volume of 2 L is required for all of the trench leachate analyses (see Sect. 2.4). The experience with trench 417 suggested that sampling using the 35-mL vials would be very time-consuming; an estimated 10 workdays would be required for each 2-L sample. Therefore, an alternative procedure in which larger (1-L) vials would be placed at the land surface and connected to the sampling tip with Teflon tubing was considered. A device for sampling in this manner required custom fabrication and was not obtained in time for sampling and subsequent analyses to be included in this report.

2.3 FIELD ANALYSES

Several chemical analyses were performed in the field as soon as the water samples were withdrawn from the well. These analyses are related primarily to water quality information and are run for parameters or conditions that would be expected to change if the samples were transported to the laboratory for subsequent analysis. These parameters include temperature, acidity (pH), dissolved oxygen (DO), oxidation/reduction (redox) potential expressed as the Ellingham voltage (Eh), and conductivity. The field analyses were conducted on unfiltered samples to avoid changing the parameters or conditions by the filtration process. (For example, aeration during filtration may increase the pH due to loss of dissolved CO_2 and may increase the Eh and DO due to addition of dissolved O_2.)

Field parameters in FY 1987 were measured using a Surveyor II water quality meter equipped with a flow-through cell (Hydrolab Corporation). The unit consists of a DO electrode, pH probe, temperature probe, redox potential probe, reference probe, depth probe, and a conductivity cell block. All sensors are housed inside a flow-through cell that allows the field measurements to be made in an anaerobic environment that is temperature compensated. Prior to FY 1987, field parameters were measured using separate analytical instruments as indicated below.

During FY 1987 temperature was measured with a thermistor-type probe with an accuracy of $\pm 0.2°C$; prior to FY 1987 a standard mercury

thermometer graduated in 0.1°C markings was used. During FY 1987 acidity was measured to an accuracy of ±0.05 pH units with a pH probe composed of a standard glass electrode and a silver/silver chloride reference electrode. The pH probe is calibrated with pH 4.00 and pH 7.00 buffer solutions according to the manufacturer's recommended procedure (Hydrolab Corporation 1985). Prior to FY 1987, pH was measured using a combination electrode with a Beckman Altec Model 71 temperature-compensated meter. DO was measured with a sensor that eletrochemically reduces the oxygen that arrives at the cathode after passing through a membrane. The accuracy of the DO measurement is about ±5% of the measured value. During FY 1987 the DO probe was calibrated using a saturated air technique as recommended by the manufacturer (Hydrolab Corporation 1985). Prior to FY 1987, DO was measured using the same type of sensor with a YSI Model 57 Dissolved Oxygen meter.

The redox potential during FY 1987 was measured using a platinum electrode with a silver/silver chloride reference electrode. The measurements were converted to Eh by adding 0.270 V to the measured voltage. (A value of 0.270 V is the potential of the reference electrode, which is referred to the hydrogen electrode.) Measurements of Eh are, at best, only a semiquantitative indication of the general redox condition of the groundwater (Wood 1976, Lindberg and Runnells 1984). The accuracy and significance of the measured Eh value depends on several factors such as state of equilibrium (or disequilibrium) between various redox couples and sensitivity (or inertness) of the platinum electrode to various redox species. These factors are, in general, unknown. In most cases, the Eh measurements should be considered only an indication of the general redox state of the groundwater sample. Redox potential was not measured during FY 1986.

Conductivity is measured using a conductivity cell. Calibration of the conductivity cell is accomplished using standard solutions of potassium chloride (KCl). The accuracy of the conductivity measurement is about ±5% of the measured value. The Surveyor II instrument (used during FY 1987) automatically compensates the DO, pH, Eh, and conductivity measurements for the solution temperature. Prior to

FY 1987, conductivity was measured using a Yellow Springs Model 31 conductivity bridge.

Alkalinity is measured by titration with 0.1 N HCl to an end point of pH 4.5. Alkalinity measurements in FY 1986 were made in the field; however, in FY 1987 unfiltered samples were collected in 100-mL polyethylene bottles and returned to the laboratory for titration within 24 h.

During FY 1987 the Surveyor II was calibrated in the laboratory prior to each SWSA 6 sampling session, and a calibration check was performed at the end of each sampling day. All calibration parameters were recorded in a logbook. The Surveyor II was remarkably stable; in no instance did the postfield calibration check differ significantly from the initial calibrated values. Prior to FY 1987, all field instruments were calibrated in the field prior to use.

All field parameters were recorded on field data sheets. Four replicate measurements of field parameters were made during FY 1987: the first just prior to sampling (see discussion that follows), the second after collection of samples for organic analyses, the third after collection of filtered nonacidified samples, and the fourth after all samples had been collected. Additional pertinent information (e.g., date, field crew, pump type, weather conditions, air temperature, standing volume of water in well, total well purge volume, and total number of samples collected) was also recorded on the field sheets. All field sheets have been placed in a registered laboratory notebook. Prior to FY 1987, only one measurement of field parameters was made.

2.4 ANALYSES PERFORMED BY ACD

A variety of analyses was performed by the ACD. Proportional counting techniques were used for the measurement of gross alpha and gross beta radioactivity. Analyses for specific alpha- and beta-emitting radionuclides require special chemical separation steps: these were performed only if the gross analyses indicated the presence of significant alpha and/or beta radioactivity. Analyses for ^{3}H, ^{14}C, and ^{99}Tc were always performed after chemical separation

because these radionuclides emit weak betas and were not effectively detected in the gross beta analysis. Gamma-emitting radionuclides were determined by gamma spectroscopy utilizing a Ge-Li detector. Total radium was determined by alpha counting after a chemical separation. Inductively coupled plasma (ICP) spectrometry was used to determine most cations. Mercury was analyzed by atomic absorption (AA) spectroscopy. Ammonia was determined by using an ion-selective electrode. Inorganic and total carbon were determined using EPA procedure 415.1, employing a nondispersive infrared detector. An ion chromatographic technique with a conductivity detector was used to determine most anions. Organic compounds identified by EPA as priority pollutants or identified in the state of Tennessee guidelines for Superfund sites were determined by gas chromatographic-mass spectrographic (GC-MS) techniques.

3. RESULTS

3.1 FIELD OBSERVATION

The field data, including acidity, temperature, DO, conductivity, and alkalinity, are shown in Table 3. Most samples have near neutral acidity and range from pH 5.7 to 8.0. Groundwater samples generally have higher pH values (ranging from pH 7.0 to 8.0) than trench leachate samples (ranging from pH 5.7 to 7.2). One trench leachate sample (T257) had a high pH of 7.8. Alkalinity was low and quite variable, ranging from 2.5 to 14.4 m$\underline{M}$ HCO_3^-. The two extreme values were both from trench samples; groundwater samples were somewhat less variable, ranging from 5.2 to 8.9 m$\underline{M}$ HCO_3^-. Although total alkalinity rather than bicarbonate was measured, the majority of the titration is due to bicarbonate (HCO_3^-) because all samples had pH values of less than 8.3. The temperature ranged from 10.5 to 25.5°C, typical values for very shallow groundwater. The samples generally showed mildly oxidizing redox conditions; however, both the Eh and DO values were quite variable. DO ranged from 0.1 to 8.2 mg/L and Eh ranged from -0.071 to +0.490 V. A positive correlation exists between the DO concentration and the Eh potential, higher DO values correlating with higher Eh values. Conductivity values ranged from 117 to 1730 µS/cm. A tracer test using a saltwater injection had previously been conducted on trench 260, and residual dissolved salinity from this test is likely the cause of the 1500-µS/cm conductivity value for this trench.

3.2 CATIONS

Most elements expected to be present as cations were analyzed using ICP spectrometry. The data are listed in Table 4. (Mercury, determined by AA, is listed in Table 5.) Calcium is the major cation in most samples. Calcium concentrations ranged from 31 mg/L in trench 163 to 1200 mg/L in groundwater sampled from well 649.

Table 3. Field parameters for leachate and groundwater samples

Well or trench and date sampled	pH	Temp (°C)	O_2 (ppm)	Conductivity (µS/cm)	Eh (V)	Alkalinity (mM HCO_3^-)	Remarks
T41 3/11/86	6.5	14.8	1.2	638	0.262	9.9	a
T41 12/4/86	6.2	16.5	NA	870	NA	10.5	
T41 3/10/87	5.7	11.7	2.6	117	NA	3.2	a,b
T92 4/22/87	7.0	17	1.8	545	0.180	2.9	
T92 12/4/86	6.2	16.3	0.8	1730	NA	14.4	
T92 3/10/87	7.0	12.6	3.0	442	NA	3.3	a,c
T135 4/13/87	6.4	14.7	0.3	930	0.009	7.7	b
T163 4/21/87	6.3	16.2	0.3	377	0.034	2.7	a
T219 1/21/87	6.6	10.5	3.2	938	NA	8.2	a,c
T257 12/5/86	6.4	14.5	1.0	320	NA	NA	
T257 1/21/87	5.8	14.1	1.5	468	NA	3.3	a,c
T257 3/10/87	7.8	12.8	4.2	283	NA	2.5	b,c
T260-2 4/13/87	5.8	13.2	0.4	1500	-0.071	3.6	a

Table 3. (continued)

Well or trench and date sampled	pH	Temp (°C)	O_2 (ppm)	Conductivity (µS/cm)	Eh (V)	Alkalinity (m$\underline{M}$ HCO_3^-)	Remarks
T288 3/21/86	6.4	10.4	0.1	480	0.860	7.1	b
T288 12/5/86	6.6	15.8	0.6	840	NA	NA	
T288 3/10/87	7.2	10.4	4.0	745	NA	6.4	a,c
S-11 3/17/86	7.0	17.0	1.8	545	0.490	8.9	b
647 7/10/86	7.0	25.5	4.2	720	0.445	7.7	
648 1/21/87	7.0	10.6	2.6	556	NA	5.2	b,c
649 3/11/87	7.9	14.1	7.0	785	NA	8.4	a,c
650 3/11/87	8.0	12.3	8.2	636	NA	5.9	b,c

NA = analysis not performed.

[a]The unacidified filtered leachate sample was initially clear; on standing 2 h, a fine brown precipitate appeared.

[b]The filtered solution remained clear for at least 24 h.

[c]The well was sampled on 2 consecutive days to get sufficient water for all analyses.

Table 4. Inductively coupled plasma spectrometric analyses of leachate and groundwater samples (in mg/L)

Element	Well ID/sampling date							
	T41 3/11/86	T41 12/4/86	T41 3/10/87	T92 4/22/86	T92 12/4/86	T92 3/10/87	T135 4/13/87	T163 4/21/87
Ag	<0.050	<0.050	<0.005	<0.050	<0.050	<0.005	<0.005	<0.005
Al	<0.200	<0.200	<0.020	<0.200	<0.200	<0.020	0.02	0.035
As	<0.330	<0.10	<0.010	<0.005	<0.10	<0.010	<0.010	<0.010
B	0.35	0.48	0.17	0.08	<0.08	0.084	0.25	0.094
Ba	0.18	0.14	0.2	0.14	0.21	0.089	0.16	0.061
Be	<0.002	<0.002	<0.0002	<0.002	<0.002	<0.0002	<0.0002	<0.0002
Ca	140	120	110	37	48	34	89	31
Cd	0.005	<0.005	0.0019	<0.005	<0.005	<0.0005	0.004	0.0016
Co	0.01	0.015	0.0068	<0.022	<0.010	0.013	0.008	0.0068
Cr	<0.040	<0.040	<0.0053	<0.040	<0.040	<0.0040	<0.0040	<0.0040
Cu	<0.020	<0.020	<0.002	<0.020	<0.020	<0.002	0.002	0.0025
Fe	23	37	34	7.1	23	6.2	50	<1.000
Ga	<0.300	<0.300	<0.030	<0.300	<0.300	<0.030	<0.030	<0.030
Li	<0.200	<0.200	<0.020	<0.200	<0.200	<0.020	<0.1900	<0.020
Mg	25	26	24	9.1	9.6	6.8	17	8.1
Mn	5	5.2	4.5	9.4	8	6.6	3.5	1.5
Mo	<0.040	<0.040	0.028	<0.040	<0.040	<0.004	<0.0040	<0.004
Na	42	28	27	7.1	23	9.8	7.1	1.8
Ni	0.08	0.27	0.034	0.06	<0.06	<0.006	<0.0120	<0.006
P	0.41	0.54	0.46	<0.300	2	0.2	1.8	0.79
Pb	<0.200	<0.200	<0.020	<0.010	<0.20	<0.020	<0.020	<0.020
Sb	<0.020	<0.20	<0.020	<0.200	<0.200	<0.020	<0.020	<0.020
Se	<0.020	<0.20	<0.020	<0.010	<0.20	<0.020	<0.020	<0.020
Si	3.9	3.6	3.3	4.7	6.2	3.8	1.9	1.1
Sn	<0.050	<0.050	<0.005	<0.050	<0.050	<0.005	<0.0050	<0.0050
Sr	0.14	0.23	0.2	0.11	0.13	0.074	0.15	0.042
Ti	<0.020	<0.020	<0.002	<0.020	<0.020	<0.002	0.002	0.0057
V	<0.010	<0.0010	0.001	<0.010	<0.0010	<0.001	0.001	0.001
Zn	0.041	0.083	0.0073	<0.020	<0.020	0.023	<0.0560	<0.0330
Zr	<0.020	<0.020	<0.002	<0.020	<0.020	<0.002	<0.0020	<0.002

Table 4. (continued)

Element	Well ID/sampling date							
	T41 3/11/86	T41 12/4/86	T41 3/10/87	T92 4/22/86	T92 12/4/86	T92 3/10/87	T135 4/13/87	T163 4/21/87
Ag	<0.03	<0.050	<0.005	<0.005	<0.005	<0.050	<0.050	<0.005
Al	<0.120	<0.200	0.03	<0.020	0.02	<0.200	<0.200	<0.020
As	<0.060	<0.10	<0.010	<0.010	<0.010	<0.005	<0.10	<0.010
B	<0.048	<0.08	0.022	<0.008	0.008	0.08	<0.08	<0.008
Ba	0.1	<0.099	0.12	0.068	0.13	0.2	0.28	0.18
Be	<0.0012	<0.002	<0.0002	<0.0002	<0.0002	<0.002	<0.002	<0.0002
Ca	150	31	36	32	38	47	72	52
Cd	<0.00	<0.005	0.0012	<0.0005	0.0033	<0.005	<0.005	0.0021
Co	0.014	<0.010	0.047	<0.001	0.019	<0.010	<0.016	0.0099
Cr	<0.024	<0.040	0.0049	<0.004	<0.0040	<0.040	<0.040	<0.004
Cu	<0.012	<0.020	<0.002	<0.002	0.002	<0.020	<0.020	<0.002
Fe	24	0.33	17	0.0087	40	50	69	45
Ga	<0.180	<0.300	<0.030	<0.030	<0.030	<0.300	<0.300	<0.030
Li	<0.120	<0.200	<0.020	<0.020	<0.0200	<0.200	<0.200	<0.020
Mg	22	4.6	11	3.7	13	13	18	12
Mn	5.7	0.35	7	0.00081	4.3	5.8	8.5	5.4
Mo	<0.024	<0.040	0.011	<0.004	<0.0040	<0.040	<0.040	0.014
Na	2.9	13	18	8.5	130	2.6	3.7	1.4
Ni	<0.036	<0.06	0.014	<0.006	<0.0060	0.06	<0.06	0.006
P	<0.180	0.62	0.12	0.13	0.1	0.63	0.84	0.64
Pb	<0.120	<0.20	<0.020	<0.020	<0.020	<0.010	<0.20	<0.020
Sb	<0.120	<0.20	<0.020	<0.020	<0.020	<0.020	<0.20	<0.020
Se	<0.120	<0.20	<0.020	<0.020	<0.020	<0.010	<0.20	<0.020
Si	0.53	2	0.14	2.1	1.3	4.3	5.4	3.3
Sn	<0.030	<0.050	<0.005	<0.005	<0.0050	<0.050	<0.050	<0.005
Sr	0.17	0.061	0.072	0.05	0.075	0.092	0.13	0.078
Ti	<0.012	<0.020	0.0048	<0.002	0.0038	<0.020	<0.020	<0.002
V	0.0097	<0.001	<0.0010	0.0018	0.001	<0.010	<0.001	<0.001
Zn	<0.012	<0.020	0.44	0.006	<0.0190	<0.020	<0.020	0.0069
Zr	<0.012	<0.020	<0.002	<0.002	<0.0020	<0.020	<0.020	<0.002

Table 4. (continued)

Element	Well ID/sampling date							
	T41 3/11/86	T41 12/4/86	T41 3/10/87	T92 4/22/86	T92 12/4/86	T92 3/10/87	T135 4/13/87	T163 4/21/87
Ag	<0.050	<0.050	<0.005	<0.050	<0.050	<0.050	<0.050	<0.005
Al	<0.200	<0.200	<0.020	<0.200	<0.200	<0.200	<0.200	<0.020
As	<0.100	<0.100	<0.010	<0.100	<0.100	<0.10	<0.10	<0.010
B	0.08	0.08	<0.008	0.32	0.11	<0.08	<0.08	<0.008
Ba	0.16	0.12	0.2	1.2	2	<0.020	<0.020	<0.014
Be	<0.002	<0.002	<0.0002	<0.0020	<0.002	<0.002	<0.002	<0.0002
Ca	140	63	90	1200	900	<5.0	1.2	0.25
Cd	<0.005	<0.005	<0.0005	<0.026	<0.0005	<0.005	<0.005	<0.0005
Co	<0.010	<0.010	0.0071	0.023	0.02	<0.010	<0.010	<0.0010
Cr	<0.040	<0.040	0.0052	<0.042	<0.045	<0.040	<0.040	<0.0040
Cu	<0.020	<0.020	<0.002	<0.020	<0.020	<0.020	<0.020	0.003
Fe	<0.030	<0.030	0.097	0.086	3.6	<0.030	<0.030	0.013
Ga	<0.300	<0.300	<0.030	<0.300	<0.300	<0.300	<0.300	<0.030
Li	<0.200	<0.200	<0.020	<0.200	<0.230	<0.200	<0.200	<0.020
Mg	24	10	6.5	78	110	0.14	0.39	0.0055
Mn	0.088	0.11	3.6	0.46	0.15	<0.0050	<0.0050	0.00056
Mo	<0.040	<0.040	<0.004	<0.040	<0.040	<0.040	<0.040	<0.004
Na	42	5.3	11	47	58	<0.50	<0.50	0.15
Ni	0.06	0.06	<0.006	<0.060	<0.060	<0.060	<0.060	<0.006
P	0.3	0.3	0.097	<0.300	<0.380	<0.300	<0.300	0.03
Pb	<0.200	<0.200	<0.020	<0.200	<0.200	<0.20	<0.20	<0.020
Sb	<0.200	<0.200	<0.020	<0.200	<0.200	<0.200	<0.200	<0.020
Se	<0.20	<0.200	<0.020	<0.200	<0.200	<0.20	<0.20	<0.020
Si	8.7	7.8	0.25	54	87	<0.20	<0.20	0.034
Sn	<0.050	<0.050	<0.0050	<0.050	<0.050	<0.050	<0.050	<0.0050
Sr	0.19	0.13	0.12	1.7	1.4	0.0065	0.0063	0.00068
Ti	<0.020	<0.020	0.0028	<0.020	<0.020	<0.020	<0.020	0.0044
V	<0.010	<0.010	0.0014	0.001	0.01	<0.0010	<0.0010	0.001
Zn	<0.020	<0.020	<0.002	<0.130	<0.096	0.03	0.022	<0.0250
Zr	<0.020	<0.020	<0.002	<0.020	<0.020	<0.020	<0.020	<0.002

Table 5. Chemical, ion chromatographic, and atomic absorption analyses of leachate and groundwater samples (in mg/L)

Analysis	Well ID/sampling date							
	T41 3/11/86	T41 12/4/86	T41 3/10/87	T92 4/22/86	T92 12/4/86	T92 3/10/87	135 4/13/87	163 4/21/87
				Chemical				
NH_3	5.31	NA	NA	2.2	NA	NA	2.56	7.05
Cyanide	NA	NA	<0.002	NA	NA	<0.002	<0.002	<0.002
Total C	189	NA	NA	88	NA	NA	NA	NA
IOC	141	NA	NA	60	NA	NA	NA	NA
TOC	NA	NA	NA	NA	NA	NA	54	10
				Ion chromatographic				
NO_3^-	<5	1.0	3	<5.0	<1	<1.0	<5.0	<5.0
F^-	<10.0	1	<1.0	<1.0	4		<1.0	<1.0
SO_4^{2+}	132	150	9	6	6	<5.0	<5.0	<5.0
Cl^-	27	500	20	17	80	14	8.3	6.2
Br^-	<5.0	<5.0	<1.0	<5.0	<5.0	<1.0	<5.0	<5.0
PO_4^{3-}	<5.0	<1.0	<1.0	<5.0	<1	<1.0	<5.0	<5.0
				Atomic absorption				
Hg	<0.0001	NA	NA	<0.0002	NA	NA	<0.0001	<0.0001

Analysis	Well ID/sampling date							
	T219 1/21/87	T257 12/5/86	T257 1/21/87	T257 3/10/87	T260-2 4/13/87	T288 3/21/86	T288 12/5/86	T288 3/10/87
				Chemical				
NH_3	7.2	NA	0.64	NA	1.64	21.8	NA	NA
Cyanide	<0.002	NA	<0.002	<0.002	<0.002	NA	NA	<0.002
Total C	NA	NA	NA	NA	NA	148	NA	NA
IOC	NA	NA	NA	NA	NA	129	NA	NA
TOC	11	NA	4.4	NA	2.5	NA	NA	NA
				Ion chromatographic				
NO_3^-	<1.0	<1.0	<1.0	4	<5.0	<5.0	<1	<1.0
F^-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	4	<1.0
SO_4^{2+}	8	5	29	5	<5.0	<5.0	<1	<1.0
Cl^-	7	5	15	4	300	9.6	48	6
Br^-	<5.0	<5.0	<5.0	<1.0	<5.0	<5.0	<5.0	<1.0
PO_4^{3-}	<1.0	1	<1.0	1.5	<5.0	<5.0	1.0	<1.0
				Atomic absorption				
Hg	<0.0002	NA	<0.0002	NA	<0.0001	<0.0001	NA	NA

Table 5. (continued)

Analysis	Well ID/sampling date					
	S11 3/17/86	647 7/10/86	648 1/21/87	649 3/11/87	650 3/11/87	Blank 4/21/87
			Chemical			
NH_3	0.18	0.24	0.11	NA	NA	0.13
Cyanide	NA	<0.002	<0.002	<0.002	<0.002	<0.002
Total C	119	NA	NA	NA	NA	NA
IOC	114	NA	NA	NA	NA	NA
TOC	NA	2.1	1.7	1.1	0.7	0.5
			Ion chromatographic			
NO_3^-	9.6	<5.0	<1.0	5	<1.0	<5.0
F^-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
SO_4^{2+}	77	<5.0	5	20	21	<5.0
Cl^-	9.6	1	5	4	4	1.0
Br^-	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
PO_4^{3-}	<5.0	<5.0	<1.0	<1.0	<1.0	<5.0
			Atomic absorption			
Hg	<0.0001	0.0007	<0.0002	<0.0001	<0.0002	<0.0001

NA = analysis not performed.
TOC = total organic carbon.
IOC = inorganic carbon.

Groundwater samples generally contained higher calcium concentrations than trench leachate samples. Other major cations include sodium, which ranged from 1 to about 130 mg/L, and magnesium, which ranged from 4 to 110 mg/L. Relatively high concentrations of iron were found; values ranged from below the detection limit to 50 mg/L.

Hazardous metals shown in Table 4 (including As, Cd, Cr, Pb, Se, and Ag) were below or very near their respective detection levels. Nickel in concentrations as high as 0.27 mg/L was detected in several samples. Mercury was detected in only one sample, at a low concentration of 0.0007 mg/L.

3.3 ANIONS

The major anions present (Table 5) are sulfate (SO_4^{2-}), chloride (Cl^-), and bicarbonate (HCO_3^-). Sulfate concentrations ranged from less than the detection limit (5.0 mg/L) to 150 mg/L. Although the highest SO_4^{2-} concentrations were in trench leachate samples, concentrations as high as 77 mg/L were measured in groundwater samples. Chloride ranged from 1 to 80 mg/L, with one extreme of 300 mg/L in trench 260, which was used previously for a saltwater tracer test. Trench leachate samples were generally enriched in chloride relative to groundwater samples.

3.4 DISSOLVED RADIONUCLIDES

The results of the radiochemical analyses are shown in Table 6. The gross alpha activity was near the detection limit for all samples with the exception of the leachate collected from trench 41, which had an activity of 8.6 $\pm$ 5.3 Bq/L when sampled on March 11, 1986, and 110 $\pm$ 45 when sampled on January 4, 1987. Concentrations of individual uranium ($^{234,235,238}U$) and thorium ($^{228,230}Th$) radionuclides from trench 41 were all below 1 Bq/L.

Table 6. Radiochemical analyses of leachate and groundwater samples (in Bq/L)

Analysis	Well ID/sampling date					
	T41 3/11/86	T41 12/4/86	T41 3/10/87	T92 4/22/86	T92 12/4/86	T92 3/10/87
Gross alpha	8.6±5.3	110±45	1.1±1.8	1.5±1.7	0.7±1.4	1±1
Gross beta	5400±100	18,000±1000	16,000±1000	150±10	16±4	9.4±3.4
Gross gamma[a]	<10	<10	<10	<10	<10	<10
^{3}H	2000±100	340,000±10,000	180,000±10,000	2200±100	2600±100	1500±100
^{14}C	1.9	NA	2900±100	42±18	NA	<21
^{60}Co	NA	<0.6	<0.6	0.22±0.08	<0.3	<0.1
^{90}Sr	3600±100	3100±100	NA	86±12	0.84±0.20	NAL
^{99}Tc	<100	<100	<100	<100	<100	<100
^{137}Cs	88±6	130±10	140±10	2.6±0.2	0.33±0.28	0.59±0.13
^{228}Th	0.17±0.2	NAL	NAL	NAL	NAL	NAL
^{230}Th	0.03±0.01	NAL	NAL	NAL	NAL	NAL
^{234}U	0.63±0.07	NAL	NAL	NAL	NAL	NAL
^{235}U	0.11±0.03	NAL	NAL	NAL	NAL	NAL
^{238}U	0.36±0.05	NAL	NAL	NAL	NAL	NAL
Total Ra	0.47±0.18	NAL	NAL	<0.02	NAL	NAL

Table 6. (continued)

Analysis	Well ID/sampling date					
	T135 4/13/87	T163 4/21/87	T219 1/21/87	T257 12/5/86	T257 1/21/87	T257 3/10/87
Gross alpha	0.6±1	1±1.7	<2.0	2.9±2.4	4.2±3	2±2.1
Gross beta	5400±100	26.±5	20±5	9.4±3.7	1100±100	1±2.4
Gross gamma[a]	<10	<10	<10	<10	<10	<10
^{3}H	33,000±1000	620±50	380±40	23,000±1000	3900±100	12,000±1000
^{14}C	2600±100	32±21	30±20	NA	410±30	1±20
^{60}Co	0.7±0.22	0.33±0.18	<2	<0.3	1.4±0.4	<0.2
^{90}Sr	NA	NAL	NAL	0.26±0.13	NA	NAL
^{99}Tc	<100	<100	<100	<100	<100	<100
^{137}Cs	40±1	2.4±0.2	3±0.4	<0.3	2.1±0.4	<0.2
^{228}Th	NAL	NAL	NAL	NAL	NAL	NAL
^{230}Th	NAL	NAL	NAL	NAL	NAL	NAL
^{234}U	NAL	NAL	NAL	NAL	NAL	NAL
^{235}U	NAL	NAL	NAL	NAL	NAL	NAL
^{238}U	NAL	NAL	NAL	NAL	NAL	NAL
Total Ra	NAL	NAL	0.11±0.05	NAL	<0.1	NAL

Table 6. (continued)

Analysis	Well ID/sampling date				
	T260-2 4/13/87	T288 3/21/86	T288 12/5/86	T288 3/10/87	S11 3/17/86
Gross alpha	0.4±1	1.9±2	2.5±2.3	1±2	7.7±2.7
Gross beta	3.9±3	4.9±2.9	52±7	9.1±3.4	4.7±2.9
Gross gamma[a]	<10	<10	<10	<10	<10
^{3}H	310±40	480±90	1200±100	570±50	3700±200
^{14}C	19±20	10±35	NA	10±20	48±36
^{60}Co	<0.2	0.88±0.26	0.43±0.29	<0.2	0.87±0.33
^{90}Sr	NAL	NAL	12±1	NAL	NAL
^{99}Tc	<100	<100	<100	<100	<100
^{137}Cs	<0.3	<0.1	1.2±0.3	0.29±0.11	<0.1
^{228}Th	NAL	NAL	NAL	NAL	NAL
^{230}Th	NAL	NAL	NAL	NAL	NAL
^{234}U	NAL	NAL	NAL	NAL	NAL
^{235}U	NAL	NAL	NAL	NAL	NAL
^{238}U	NAL	NAL	NAL	NAL	NAL
Total Ra	NAL	<0.02	NAL	NAL	<0.02

Table 6. (continued)

Analysis	Well ID/sampling date				
	647 7/10/86	648 1/21/87	649 3/11/87	650 3/11/87	Blank 4/21/87
Gross alpha	1.6±2	<2	1±2	1±1	0.4±1.4
Gross beta	5.3±3	<3	<2	2.6±2.6	0.7±2.3
Gross gamma[a]	<10	<10	<10	<10	<10
^{3}H	34±21	71±24	15±20	26,000±1000	24±21
^{14}C	8±18	25±20	<20	13±14	6±20
^{60}Co	<0.1	<3	<0.5	<0.1	<0.3
^{90}Sr	NAL	NAL	NAL	NAL	NAL
^{99}Tc	<100	<100	<100	<100	<100
^{137}Cs	<0.1	<0.3	<0.4	<0.1	<0.3
^{228}Th	NAL	NAL	NAL	NAL	NAL
^{230}Th	NAL	NAL	NAL	NAL	NAL
^{234}U	NAL	NAL	NAL	NAL	NAL
^{235}U	NAL	NAL	NAL	NAL	NAL
^{238}U	NAL	NAL	NAL	NAL	NAL
Total Ra	0.025±0.012	0.064±0.042	NAL	NAL	NAL

[a]Units are (counts•min^{-1}•mL^{-1}).
NA = analysis not performed.
NAL = analysis not performed because gross activity was low.

Tritium is ubiquitous in trench leachate and groundwater samples from SWSA 6. The activity of ^{3}H ranged from near the detection limit in well 649 to 340,000 ± 10,000 Bq/L in trench 41. The lowest ^{3}H activity measured in trench leachate was 310 ± 40 Bq/L in trench 260. Concentrations of ^{3}H in excess of 1000 Bq/L were measured in 11 of the 16 leachate samples collected. Tritium concentrations in excess of 1000 Bq/L were also measured in two of the five groundwater samples collected.

Other beta-emitting radionuclides, including ^{90}Sr and ^{14}C, were also detected. Specific ^{90}Sr analyses were performed on six samples, which showed gross beta activities ranging from 0.26 ± 0.13 Bq/L to 3600 ± 100 Bq/L. Since the gross beta analysis is done using a beta proportional counter standardized for a ^{90}Sr-^{90}Y mixture, the gross beta analysis is essentially a qualitative analysis for ^{90}Sr. Significant concentrations of ^{90}Sr were not detected in any of the groundwater samples. Carbon-14 activities ranged from below detection to as high as 2900 ± 100 Bq/L. Activities greater than 1000 Bq/L were measured in only two of the trench leachate samples. None of the groundwater samples had significant ^{14}C activities. Technetium-99 was below the detection limit of 100 Bq/L in all samples.

Gamma scans were performed on all of the samples; only low levels of ^{60}Co and ^{137}Cs were detected. Cobalt-60 analyses for all samples were very near the detection limit, with the highest activity of 1.4 ± 0.4 Bq/L occurring in leachate from trench 257. Cesium-137 was above the detection limit in 12 of the trench leachate samples. The highest ^{137}Cs activity occurred in leachate from trench 41 (130 ± 10 Bq/L). Cesium-137 was below the detection limit in all of the groundwater samples. Total radium was near the detection limit of 0.02 Bq/L in all of the samples.

A comparison of ^{3}H, ^{60}Co, and ^{90}Sr activities for each trench and groundwater sample is shown in Fig. 3. (Average concentrations are shown when more than one analysis from a single trench was available.) As might be expected considering the heterogeneity of the wastes and waste containerization, little correlation is apparent.

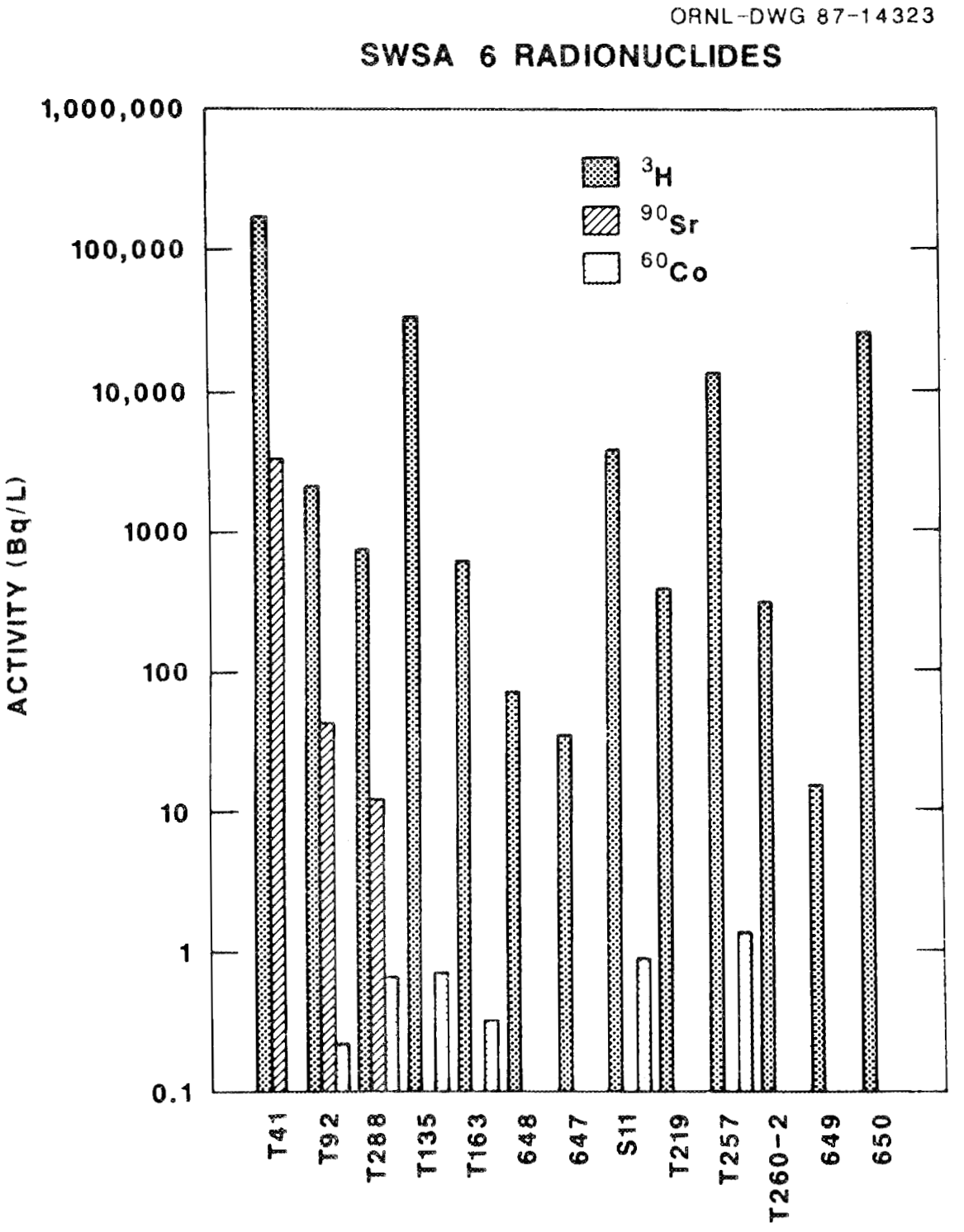

Fig. 3. Activity of ^{3}H, ^{90}Sr, and ^{60}Co in trench leachate and groundwater samples from SWSA 6.

3.5 DISSOLVED ORGANIC COMPOUNDS

A total of 21 EPA priority pollutant organic compounds was detected in various samples; data are presented in Table 7. Twelve of these compounds were detected in more than one sample: methylene chloride, 1,1-dichloroethane, chloroform, trichloroethene, benzene, tetrachloroethene, toluene, ethylbenzene, total xylenes, phenol, 4-methylphenol, and naphthalene.

The detection limit for all of the EPA priority pollutant organic compounds is very low (ppb range); therefore, caution should be exercised in considering the significance of low values. Most of the samples were collected from monitoring wells constructed of stainless steel that had been scrupulously cleaned and should have been free of extraneous organics. However, three of the wells sampled were constructed of PVC, which can sorb and/or release organic compounds (Barcelona et al. 1985). The concentrations reported in Table 7 should be used only in a semiquantitative sense, and the reported occurrence of organics in concentrations only slightly above detection should be further confirmed.

Several organic compounds were detected at concentrations well above the detection limit. In addition, several of these compounds were found in more than one well sample. There would seem to be little ambiguity concerning the presence of these priority pollutants in SWSA 6 samples. Trichloroethene, benzene, tetrachloroethene, toluene, and naphthalene were detected in concentrations near 1 mg/L, which is about 100 to 500 times greater than the detection limits. Tetrachloroethene, toluene, and naphthalene were all detected in significant concentrations in more than one sample, and, therefore, these three compounds may be the most widespread or prevalent mobile organic contaminants in SWSA 6.

Table 7. Gas chromatographic-mass spectrographic analyses of leachate and groundwater samples (in µgL)

Compound	Well ID/sampling date					
	T92 4/22/86	T135 4/13/87	T163 4/21/87	T219 1/21/87	T257 1/21/87	T260-2 4/13/87
Chloromethane	<10	<10	<10	<10	<10	<10
Bromomethane	<10	<10	<10	<10	<10	<10
Vinyl chloride	<10	<5	<5	<10	<10	<5
Chloroethane	<10	<10	49	<10	<10	<10
Methylene chloride	<2.8	<5	<5	<5	<5	<5
Acetone	<10	<10	<8	<10	<10	<10
Carbon disulfide	<5	<5	<5	<5	<5	<5
1,1-Dichloroethene	<2.8	<5	<5	<5	<5	<5
1,1-Dichloroethane	<4.7	<5	626	<5	<5	<5
trans-1,2-Dichloroethene	<1.6	<10	<10	<5	<5	<10
Chloroform	<1.6	<5	<5	<5	<5	<5
1,2-Dichloroethane	<2.8	<5	<5	<5	<5	<5
2-Butanone	<10	<10	<12	<10	<10	<10
1,1,1-Trichloroethane	<3.8	<5	<6	<5	<5	<5
Carbon tetrachloride	<2.8	<5	<5	<5	<5	<5
Vinyl acetate	<10	<10	<10	<10	<10	<10
Bromodichloromethane	<2.2	<5	<5	<5	<5	<5
1,1,2,2-Tetrachloroethane	<6.9	<5	<5	<5	<5	<5
1,2-Dichloropropane	<6	<5	<5	<5	<5	<5
trans-1,3-Dichloropropene	<5	<5	<5	<5	<5	<5
Trichloroethene	2	<5	<5	8	<5	<5
Chlorodibromomethane	<5	<5	<5	<5	<5	<5
1,1,2-Trichloroethane	<5	<5	<5	<5	<5	<5
Benzene	4.4	<5	<5	929	<5	<5
cis-1,3-Dichloropropene	<5	<5	<5	58	<5	<5
2-Chloroethylvinyl ether	<10	<10	<10	<10	<10	<10
Bromoform	<4.7	<5	<5	<5	<5	<5
2-Hexanone	<10	<10	<10	<10	<10	<10
4-Methyl-2-pentanone	<10	<10	<10	<10	<10	<10
Tetrachloroethene	<4.1	<5	<5	1182	<5	<5
Toluene	<5	14	668	<5	35	<5
Chlorobenzene	<5	<5	<5	<5	<5	<5
Ethylbenzene	<5	<5	<5	67	<5	<5
Styrene	<5	<5	<5	7	<5	<5
Total xylenes	<5	<5	<5	3696	11	<5
Phenol	<10	<10	12	<10	<10	<10
bis(2-Chloroethyl)ether	<10	<10	<10	<10	<10	<10
2-Chlorophenol	<10	<10	<10	<10	<10	<10
1,2-Dichlorobenzene	<10	<10	<10	<10	<10	<10
1,4-Dichlorobenzene	<10	<10	<10	<10	<10	<10
Benzyl alcohol	<10	<10	<10	<10	<10	<10
1,2-Dichlorobenzene	<10	<10	<10	<10	<10	<10
2-Methylphenol	<10	<10	<10	<10	<10	<10

Table 7. (continued)

Compound	Well ID/sampling date					
	T92 4/22/86	T135 4/13/87	T163 4/21/87	T219 1/21/87	T257 1/21/87	T260-2 4/13/87
bis(2-Chloroisopropyl)ether	<10	<10	<10	<10	<10	<10
4-Methylphenol	<10	<10	91	34	<10	<10
N-nitrosodipropylamine	<20	<10	<20	<20	<20	<10
Hexachloroethane	<10	<10	<10	<10	<10	<10
Nitrobenzene	<10	<10	<10	<10	<10	<10
Isophorone	<10	<10	<10	<10	<10	<10
2-Nitrophenol	<20	<10	<10	<20	<20	<10
2,4-Dimethylphenol	<10	<10	<10	<10	<10	<10
Benzoic acid	<50	<50	<50	<50	<50	<50
bis(2-Chloroethoxy)methane	<10	<10	<10	<10	<10	<10
2,4-Dichlorophenol	<10	<10	<10	<10	<10	<10
1,2,4-Trichlorobenzene	<10	<10	<10	<10	<10	<10
Naphthalene	51	<10	<10	354	<10	<10
4-Chloroaniline	<10	<10	<10	<10	<10	<10
Hexachlorobutadiene	<10	<10	<10	<10	<10	<10
4-Chloro-3-methylphenol	<10	<10	<10	<10	<10	<10
2-Methylnaphthalene	<10	<10	<10	<10	<10	<10
Hexachlorocyclopentadiene	<10	<10	<10	<10	<10	<10
2,4,6-Trichlorophenol	<10	<10	<10	<10	<10	<10
2,4,5-Trichlorophenol	<10	<50	<50	<50	<50	<50
2-Chloronaphthalene	<10	<10	<10	<10	<10	<10
Dimethyl phthalate	<10	<10	<10	<10	<10	<10
Acenaphthylene	<10	<10	<10	<10	<10	<10
Acenaphthene	<10	<10	<10	<10	<10	<10
2,4-Dinitrophenol	<50	<50	<50	<50	<50	<50
4-Nitrophenol	<50	<50	<50	<50	<50	<50
Dibenzofuran	<10	<10	<10	<10	<10	<10
2,4-Dinitrotoluene	<10	<10	<10	<10	<10	<10
Dinitrotoluene	<10	<10	<10	<10	<10	<10
Diethylphthalate	<10	<10	<10	<10	<10	<10
4-Chlorophenyl-phenylether	<10	<10	<10	<10	<10	<10
Fluorene	<10	<10	<10	<10	<10	<10
4,6-Dinitro-2-methylphenol	<20	<50	<50	<50	<50	<50
N-nitrosodiphenylamine (1)	<20	<10	<10	<10	<10	<10
4-Bromophenyl-phenylether	<10	<10	<10	<10	<10	<10
Hexachlorobenzene	<10	<10	<10	<10	<10	<10
Pentachlorophenol	<50	<50	<50	<50	<50	<50
Phenanthrene	<10	<10	<10	<10	<10	<10
Anthracene	<10	<10	<10	<10	<10	<10
Di-N-butylphthalate	<10	<10	<10	<10	<10	<10
Fluoranthene	<10	<10	<10	<10	<10	<10
Pyrene	<10	<10	<10	<10	<10	<10
Butylbenzylphthalate	<10	<10	<10	<10	<10	<10

Table 7. (continued)

Compound	Well ID/sampling date					
	T92 4/22/86	T135 4/13/87	T163 4/21/87	T219 1/21/87	T257 1/21/87	T260-2 4/13/87
3,3-Dichlorobenzidine	<50	<20	<20	<20	<50	<20
Benz(a)anthracene	<10	<10	<10	<10	<10	<10
bis(2-Ethylhexyl)phthalate	<10	<10	<10	<10	<10	<10
Chrysene	<10	<10	<10	<10	<10	<10
Di-N-octyl phthalate	<10	<10	<10	<10	<10	<10
Benzo(b)fluoranthene	<10	<10	<10	<10	<10	<10
Benzo(k)fluoranthene	<10	<10	<10	<10	<10	<10
Benzo(a)pyrene	<10	<10	<10	<10	<10	<10
Indeno(1,2,3-CD)pyrene	<10	<10	<10	<10	<10	<10
Dibenz(a,h)anthracene	<20	<10	<10	<10	<20	<10
Benzo(g,h,i perylene	<20	<10	<10	<10	<20	<10
p-Chloro-m-cresol	<10	<10	<10	<10	<10	<10
o-Cresol	<10	<10	<10	<10	<10	<10
p-Cresol	<10	<10	<10	<10	<10	<10
N-nitrosodimethylamine	<10	<10	<10	<10	<10	<10
Benzidine	<50	<50	<50	<50	<50	<50
1,2-Diphenylhydrazine	<20	<20	<20	<20	<20	<20
Aldrin	<10	<10	<10	<10	<10	<10
Dieldrin	<10	<10	<10	<10	<10	<10
Chlordane	<10	<10	<10	<10	<10	<10
4,4'-DDT	<10	<10	<10	<10	<10	<10
4,4'-DDE	<10	<10	<10	<10	<10	<10
4,4'-DDD	<10	<10	<10	<10	<10	<10
Endosulfan I	<10	<10	<10	<10	<10	<10
Endosulfan II	<10	<10	<10	<10	<10	<10
Endosulfan sulfate	<10	<10	<10	<10	<10	<10
Aniline	<10	<10	<10	<10	<10	<10
Benzyl alcohol	<10	<10	<10	<10	<10	<10
2-Nitroaniline	<10	<10	<10	<10	<10	<10
3-Nitroaniline	<10	<10	<10	<10	<10	<10
4-Nitroaniline	<10	<10	<10	<10	<10	<10
Endrin	<10	<10	<10	<10	<10	<10
Endrin aldehyde	<10	<10	<10	<10	<10	<10
Heptachlor	<10	<10	<10	<10	<10	<10
Heptachlor epoxide	<10	<10	<10	<10	<10	<10
Alpha-BHC	<10	<10	<10	<10	<10	<10
Beta-BHC	<10	<10	<10	<10	<10	<10
Gamma-BHC (lindane)	<10	<10	<10	<10	<10	<10
Delta-BHC	<10	<10	<10	<10	<10	<10

Table 7. (continued)

Compound	Well ID/sampling date			
	T288* 4/29/86	S11 3/17/86	647 7/10/87	648 1/21/87
Chloromethane	<10	<10	<10	<10
Bromomethane	<10	<10	<10	<10
Vinyl chloride	<10	<10	<10	<10
Chloroethane	<10	<10	<10	<10
Methylene chloride	<2.8	256	<5	<5
Acetone	<10	<10	<10	<10
Carbon disulfide	<5	<5	<5	<5
1,1-Dichloroethene	<2.8	<5	<2.8	11
1,1-Dichloroethane	<4.7	<5	10	<5
trans-1,2-Dichloroethene	<1.6	<5	<1.6	<5
Chloroform	<1.6	87	<1.6	85
1,2-Dichloroethane	<2.8	<5	<2.8	23
2-Butanone	<10	<10	<10	<10
1,1,1-Trichloroethane	<2.8	<5	<3.8	<5
Carbon tetrachloride	<2.6	<5	<2.8	<5
Vinyl acetate	<10	<10	<10	<10
Bromodichloromethane	<2.2	<5	<5	<5
1,1,2,2-Tetrachloroethane	<6.9	<5	<6.9	55
1,2-Dichloropropane	<6	<5	<6	<5
trans-1,3-Dichloropropene	<5	<5	<5	<5
Trichloroethene	<1.9	2	<1.9	2323
Chlorodibromomethane	<5	<5	<5	<5
1,1,2-Trichloroethane	<5	<5	<5	22
Benzene	13	<5	<4.4	70
cis-1,3-Dichloropropene	<5	<5	<5	<5
2-Chloroethylvinyl ether	<10	<10	<10	<10
Bromoform	<4.7	<5	<5	<5
2-Hexanone	<10	<10	<10	<10
4-Methyl-2-pentanone	<10	<10	<10	<10
Tetrachloroethene	<4.1	<5	<5	1973
Toluene	1940	<5	<5	10
Chlorobenzene	<5	<5	<5	<5
Ethylbenzene	720	<5	<5	<5
Styrene	<5	<5	<5	<5
Total xylenes	<5	<5	<5	6
Phenol	13	<10	<10	<10
bis(2-Chloroethyl)ether	<10	<10	<10	<10
2-Chlorophenol	<10	<10	<10	<10
1,2-Dichlorobenzene	<10	<10	<10	<10
1,4-Dichlorobenzene	<10	<10	<10	<10
Benzyl alcohol	<10	<10	<10	<10
1,2-Dichlorobenzene	<10	<10	<10	<10
2-Methylphenol	<10	<10	<10	<10

Table 7. (continued)

Compound	Well ID/sampling date			
	T288* 4/29/86	S11 3/17/86	647 7/10/87	648 1/21/87
bis(2-Chloroisopropyl)ether	<10	<10	<10	<10
4-Methylphenol	<10	<10	<10	<10
N-nitrosodipropylamine	<20	<20	<20	<20
Hexachloroethane	<10	<10	<10	<10
Nitrobenzene	<10	<10	<10	<10
Isophorone	<10	<10	<10	<10
2-Nitrophenol	<20	<20	<20	<20
2,4-Dimethylphenol	32	<10	<10	<10
Benzoic acid	<50	<50	<50	<50
bis(2-Chloroethoxy)methane	<10	<10	<10	<10
2,4-Dichlorophenol	<10	<10	<10	<10
1,2,4-Trichlorobenzene	<10	<10	<10	<10
Naphthalene	1704	<10	<10	<10
4-Chloroaniline	<10	<10	<10	<10
Hexachlorobutadiene	<10	<10	<10	<10
4-Chloro-3-methylphenol	<10	<10	<10	<10
2-Methylnaphthalene	<10	<10	<10	<10
Hexachlorocyclopentadiene	<10	<10	<10	<10
2,4,6-Trichlorophenol	<10	<10	<10	<10
2,4,5-Trichlorophenol	<10	<10	<10	<50
2-Chloronaphthalene	<10	<10	<10	<10
Dimethyl phthalate	<10	<10	<10	<10
Acenaphthylene	<10	<10	<10	<10
Acenaphthene	<10	<10	<10	<10
2,4-Dinitrophenol	<50	<50	<50	<50
4-Nitrophenol	<50	<50	<50	<50
Dibenzofuran	<10	<10	<10	<10
2,4-Dinitrotoluene	<10	<10	<10	<10
Dinitrotoluene	<10	<10	<10	<10
Diethylphthalate	<10	<10	<10	<10
4-Chlorophenyl-phenylether	<10	<10	<10	<10
Fluorene	<10	<10	<10	<10
4,6-Dinitro-2-methylphenol	<20	<20	<20	<50
N-nitrosodiphenylamine (1)	<20	<20	<20	<10
4-Bromophenyl-phenylether	<10	<10	<10	<10
Hexachlorobenzene	<10	<10	<10	<10
Pentachlorophenol	<50	<50	<50	<50
Phenanthrene	<10	<10	<10	<10
Anthracene	<10	<10	<10	<10
Di-N-butylphthalate	<10	<10	<10	<10
Fluoranthene	10	<10	<10	<10
Pyrene	<10	<10	<10	<10
Butylbenzylphthalate	<10	<10	<10	<10

Table 7. (continued)

Compound	Well ID/sampling date			
	T288* 4/29/86	S11 3/17/86	647 7/10/87	648 1/21/87
3,3-Dichlorobenzidine	<50	<50	<50	<20
Benz(a)anthracene	<10	<10	<10	<10
bis(2-Ethylhexyl)phthalate	<10	13	<10	<10
Chrysene	<10	<10	<10	<10
Di-N-octyl phthalate	<10	<10	<10	<10
Benzo(b)fluoranthene	<10	<10	<10	<10
Benzo(k)fluoranthene	<10	<10	<10	<10
Benzo(a)pyrene	<10	<10	<10	<10
Indeno(1,2,3-CD)pyrene	<10	<10	<10	<10
Dibenz(a,h)anthracene	<20	20	<20	<10
Benzo(g,h,i)perylene	<20	<20	<20	<10
p-Chloro-m-cresol	<10	<10	<10	<10
o-Cresol	26	<10	<10	<10
p-Cresol	141	<10	<10	<10
N-nitrosodimethylamine	<10	<10	<10	<10
Benzidine	<50	<50	<50	<50
1,2-Diphenylhydrazine	<20	<20	<20	<20
Aldrin	<10	<10	<10	<10
Dieldrin	<10	<10	<10	<10
Chlordane	<10	<10	<10	<10
4,4'-DDT	<10	<10	<10	<10
4,4'-DDE	<10	<10	<10	<10
4,4'-DDD	<10	<10	<10	<10
Endosulfan I	<10	<10	<10	<10
Endosulfan II	<10	<10	<10	<10
Endosulfan sulfate	<10	<10	<10	<10
Aniline	<10	<10	<10	<10
Benzyl alcohol	<10	<10	<10	<10
2-Nitroaniline	<10	<10	<10	<10
3-Nitroaniline	<10	<10	<10	<10
4-Nitroaniline	<10	<10	<10	<10
Endrin	<10	<10	<10	<10
Endrin aldehyde	<10	<10	<10	<10
Heptachlor	<10	<10	<10	<10
Heptachlor epoxide	<10	<10	<10	<10
Alpha-BHC	<10	<10	<10	<10
Beta-BHC	<10	<10	<10	<10
Gamma-BHC (lindane)	<10	<10	<10	<10
Delta-BHC	<10	<10	<10	<10

Table 7. (continued)

Compound	Well ID/sampling date		
	649 3/11/87	650 3/11/87	Blank 4/21/87
Chloromethane	<10	<10	<10
Bromomethane	<10	<10	<10
Vinyl chloride	<10	<10	<10
Chloroethane	<10	<10	<10
Methylene chloride	40	<5	<5
Acetone	<10	<10	36
Carbon disulfide	<5	<5	<5
1,1-Dichloroethene	<5	<5	<5
1,1-Dichloroethane	<5	<5	<5
trans-1,2-Dichloroethene	<5	<5	<10
Chloroform	<5	<5	<5
1,2-Dichloroethane	<5	<5	<5
2-Butanone	<12	<10	<10
1,1,1-Trichloroethane	<5	<5	<6
Carbon tetrachloride	<5	<5	<5
Vinyl acetate	<10	<10	<10
Bromodichloromethane	<5	<5	<5
1,1,2,2-Tetrachloroethane	<5	<5	<5
1,2-Dichloropropane	<5	<5	<5
trans-1,3-Dichloropropene	<5	<5	<5
Trichloroethene	<5	<5	<5
Chlorodibromomethane	<5	<5	<5
1,1,2-Trichloroethane	<5	<5	<5
Benzene	<5	<5	<5
cis-1,3-Dichloropropene	<5	<5	<5
2-Chloroethylvinyl ether	<10	<10	<10
Bromoform	<5	<5	<5
2-Hexanone	<10	<10	<10
4-Methyl-2-pentanone	<10	<10	<10
Tetrachloroethene	<5	<5	<5
Toluene	<5	<5	<5
Chlorobenzene	<5	<5	<5
Ethylbenzene	<5	<5	<5
Styrene	<5	<5	<5
Total xylenes	<5	<5	<5
Phenol	<10	<10	<10
bis(2-Chloroethyl)ether	<10	<10	<10
2-Chlorophenol	<10	<10	<10
1,2-Dichlorobenzene	<10	<10	<10
1,4-Dichlorobenzene	<10	<10	<10
Benzyl alcohol	<10	<10	<10
1,2-Dichlorobenzene	<10	<10	<10
2-Methylphenol	<10	<10	<10

Table 7. (continued)

Compound	Well ID/sampling date 649 3/11/87	650 3/11/87	Blank 4/21/87
bis(2-Chloroisopropyl)ether	<10	<10	<10
4-Methylphenol	<10	<10	<10
N-nitrosodipropylamine	<20	<20	<20
Hexachloroethane	<10	<10	<10
Nitrobenzene	<10	<10	<10
Isophorone	<10	<10	<10
2-Nitrophenol	<20	<20	<10
2,4-Dimethylphenol	<10	<10	<10
Benzoic acid	<50	<50	<50
bis(2-Chloroethoxy)methane	<10	<10	<10
2,4-Dichlorophenol	<10	<10	<10
1,2,4-Trichlorobenzene	<10	<10	<10
Naphthalene	<10	<10	<10
4-Chloroaniline	<10	<10	<10
Hexachlorobutadiene	<10	<10	<10
4-Chloro-3-methylphenol	<10	<10	<10
2-Methylnaphthalene	<10	<10	<10
Hexachlorocyclopentadiene	<10	<10	<10
2,4,6-Trichlorophenol	<10	<10	<10
2,4,5-Trichlorophenol	<50	<50	<50
2-Chloronaphthalene	<10	<10	<10
Dimethyl phthalate	<10	<10	<10
Acenaphthylene	<10	<10	<10
Acenaphthene	<10	<10	<10
2,4-Dinitrophenol	<50	<50	<50
4-Nitrophenol	<50	<50	<50
Dibenzofuran	<10	<10	<10
2,4-Dinitrotoluene	<10	<10	<10
Dinitrotoluene	<10	<10	<10
Diethylphthalate	<10	<10	<10
4-Chlorophenyl-phenylether	<10	<10	<10
Fluorene	<10	<10	<10
4,6-Dinitro-2-methylphenol	<50	<50	<50
N-nitrosodiphenylamine (1)	<10	<10	<10
4-Bromophenyl-phenylether	<10	<10	<10
Hexachlorobenzene	<10	<10	<10
Pentachlorophenol	<50	<50	<50
Phenanthrene	<10	<10	<10
Anthracene	<10	<10	<10
Di-N-butylphthalate	<10	<10	<10
Fluoranthene	<10	<10	<10
Pyrene	<10	<10	<10
Butylbenzylphthalate	<10	<10	<10

Table 7. (continued)

Compound	Well ID/sampling date 649 3/11/87	650 3/11/87	Blank 4/21/87
3,3-Dichlorobenzidine	<10	<10	<20
Benz(a)anthracene	<10	<10	<10
bis(2-Ethylhexyl)phthalate	<10	<10	<10
Chrysene	<10	<10	<10
Di-N-octyl phthalate	<10	<10	<10
Benzo(b)fluoranthene	<10	<10	<10
Benzo(k)fluoranthene	<10	<10	<10
Benzo(a)pyrene	<10	<10	<10
Indeno(1,2,3-CD)pyrene	<10	<10	<10
Dibenz(a,h)anthracene	<10	<10	<10
Benzo(g,h,i)perylene	<10	<10	<10
p-Chloro-m-cresol	<10	<10	<10
o-Cresol	<10	<10	<10
p-Cresol	<10	<10	<10
N-nitrosodimethylamine	<10	<10	<10
Benzidine	<50	<50	<50
1,2-Diphenylhydrazine	<20	<20	<20
Aldrin	<10	<10	<10
Dieldrin	<10	<10	<10
Chlordane	<10	<10	<10
4,4'-DDT	<10	<10	<10
4,4'-DDE	<10	<10	<10
4,4'-DDD	<10	<10	<10
Endosulfan I	<10	<10	<10
Endosulfan II	<10	<10	<10
Endosulfan sulfate	<10	<10	<10
Aniline	<10	<10	<10
Benzyl alcohol	<10	<10	<10
2-Nitroaniline	<10	<10	<10
3-Nitroaniline	<10	<10	<10
4-Nitroaniline	<10	<10	<10
Endrin	<10	<10	<10
Endrin aldehyde	<10	<10	<10
Heptachlor	<10	<10	<10
Heptachlor epoxide	<10	<10	<10
Alpha-BHC	<10	<10	<10
Beta-BHC	<10	<10	<10
Gamma-BHC (lindane)	<10	<10	<10
Delta-BHC	<10	<10	<10

*Original sample collected on 3/21/86. Measured concentration much greater than calibration range. Well resampled and analysis repeated.

4. DISCUSSION

4.1 VARIATION IN TRENCH LEACHATE WITH TIME

Trenches 41, 92, 257, and 288 were sampled on three separate dates to explore variations in contaminant concentration and major components in trench leachate with time. Figures 4 through 7 show ^{3}H, ^{137}Cs, and gross beta activity variations with time for each of these trenches. The tritium activity was relatively constant in trenches 92 and 288. Large variations were observed, however, in trench 41 and, to a lesser extent, in trench 257. Tritium in trench 41 varied from 2000 $\pm$ 100 Bq/L on March 11, 1986, to 340,000 $\pm$ 10,000 Bq/L on December 4, 1986, with an intermediate value of 180,000 $\pm$ 10,000 Bq/L on March 10, 1987. Cesium-137 varied by approximately a factor of 10, which is considerably less than the ^{3}H variation. Gross beta varied by as much as a factor of 100; because the gross beta measurement is calibrated for a ^{90}Sr-^{90}Y mixture, it represents primarily the ^{90}Sr activity of the sample. Very little variation in the major ion chemistry was observed in these leachate samples (Tables 4 and 5).

Variations in gross beta activity and ^{137}Cs are correlated in time; however, less correlation between ^{3}H and either ^{137}Cs or ^{90}Sr is apparent in these figures. The correlation between ^{137}Cs and ^{90}Sr might be expected because their release from the bulk waste may be controlled by the leaching process. Tritium, however, is probably present in an aqueous form (HTO), so its release from the bulk waste may result from container degradation.

The importance of hydrology in controlling concentrations of radionuclides in trench leachates can be seen be examining Figs. 4 through 7 (which show leachate radioactivity), along with Fig. 8 (which shows water level elevations in trench 92 as a function of time). The water level elevation in trench 92 can be used as an index of the relative soil-water status in SWSA 6. The samples collected during March and April 1986 represent the lower water level conditions of the three sampling events. The December 1986 sampling occurred during much

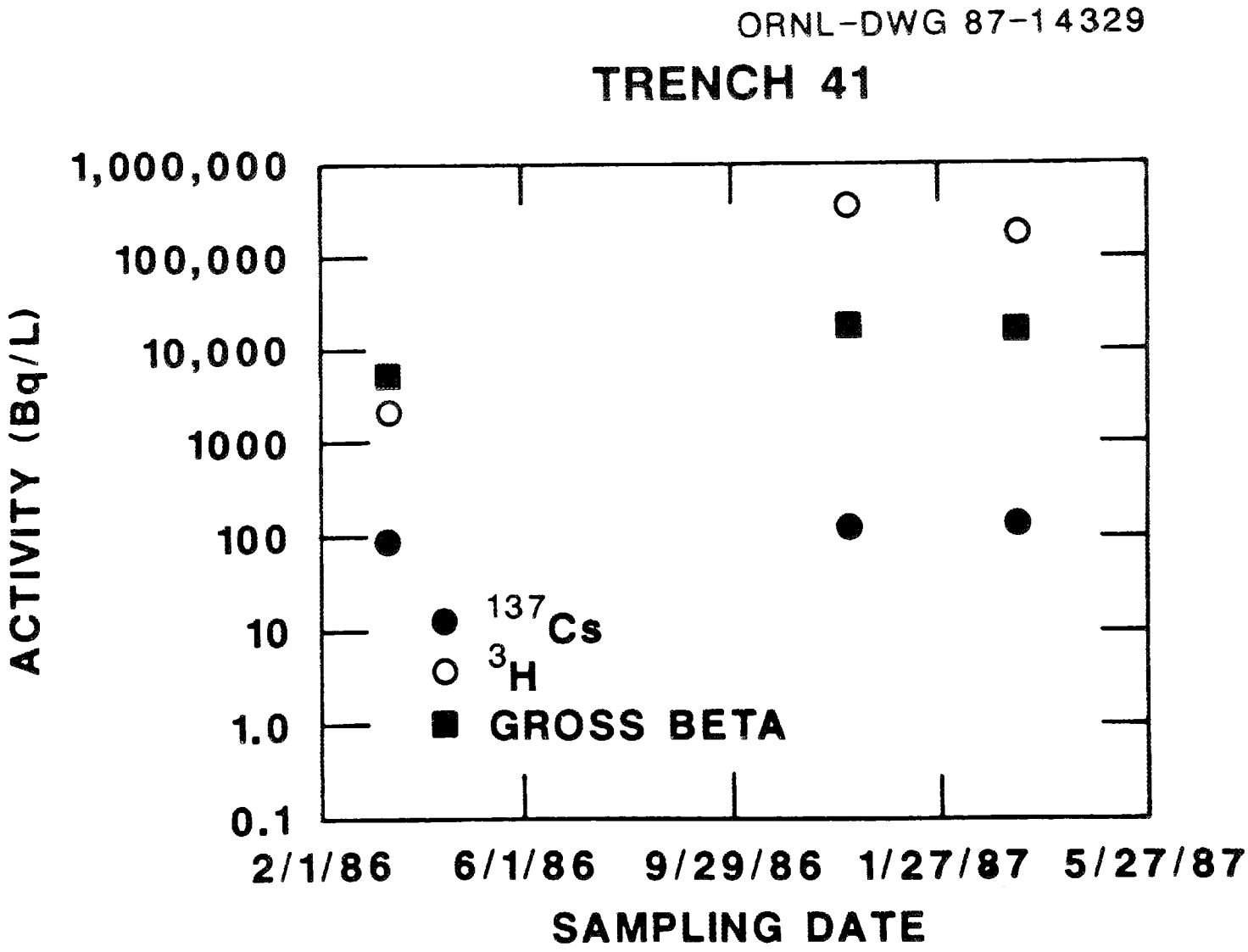

Fig. 4. Variation of ^{137}Cs, ^{3}H, and gross beta activity with time in trench 41.

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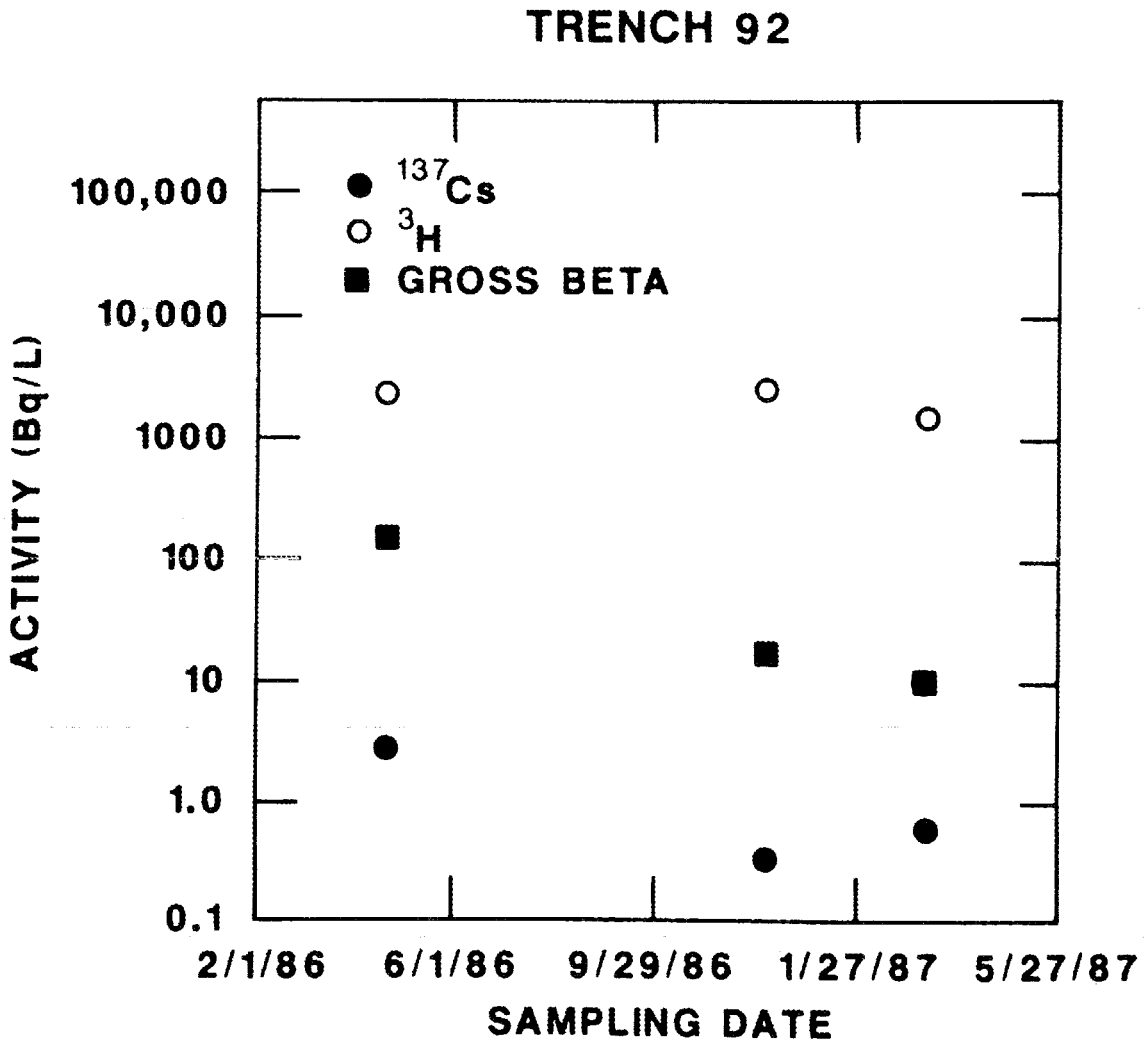

Fig. 5 Variation of ^{137}Cs, ^{3}H, and gross beta activity with time in trench 92.

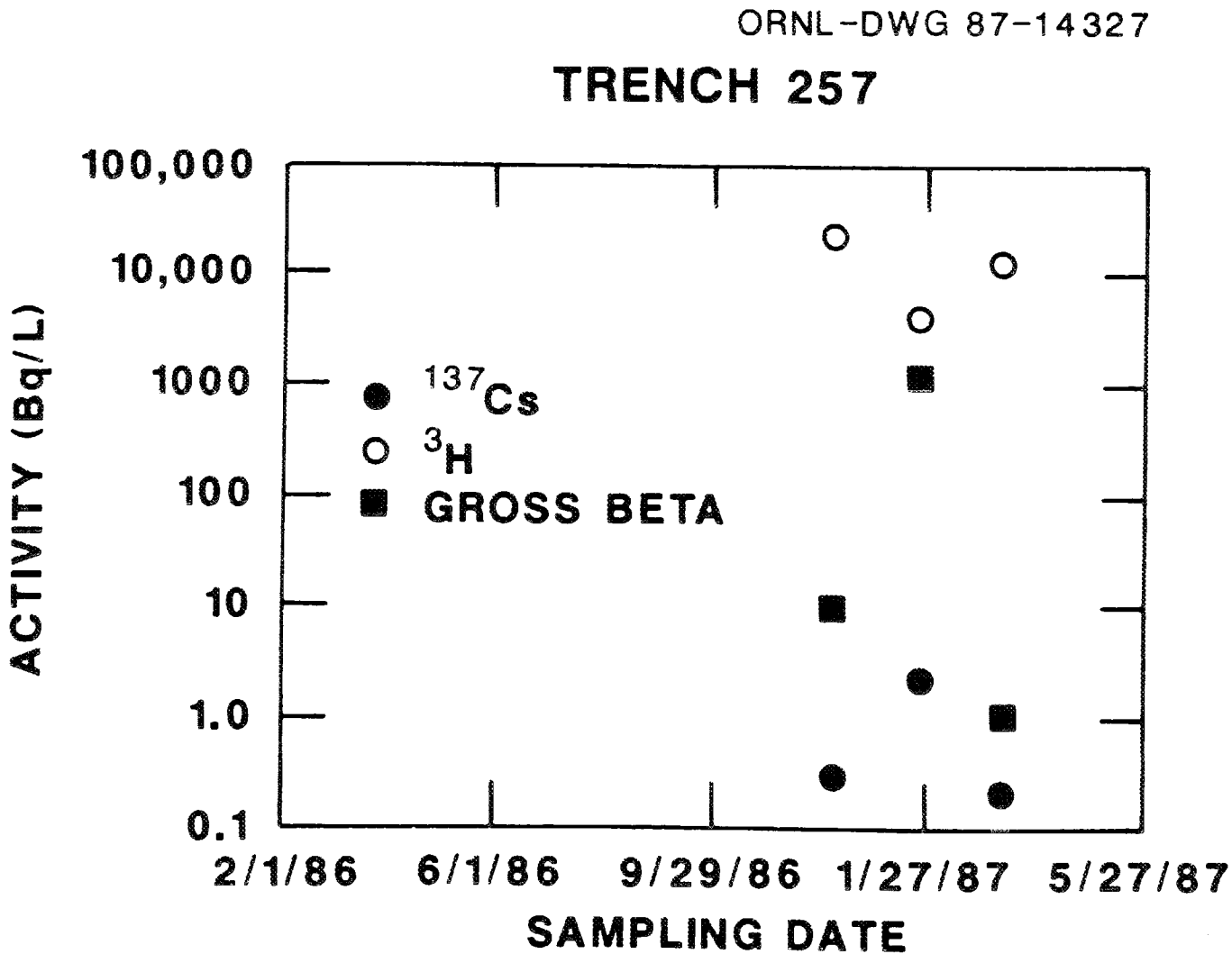

Fig. 6. Variation of ^{137}Cs, ^{3}H, and gross beta activity with time in trench 257.

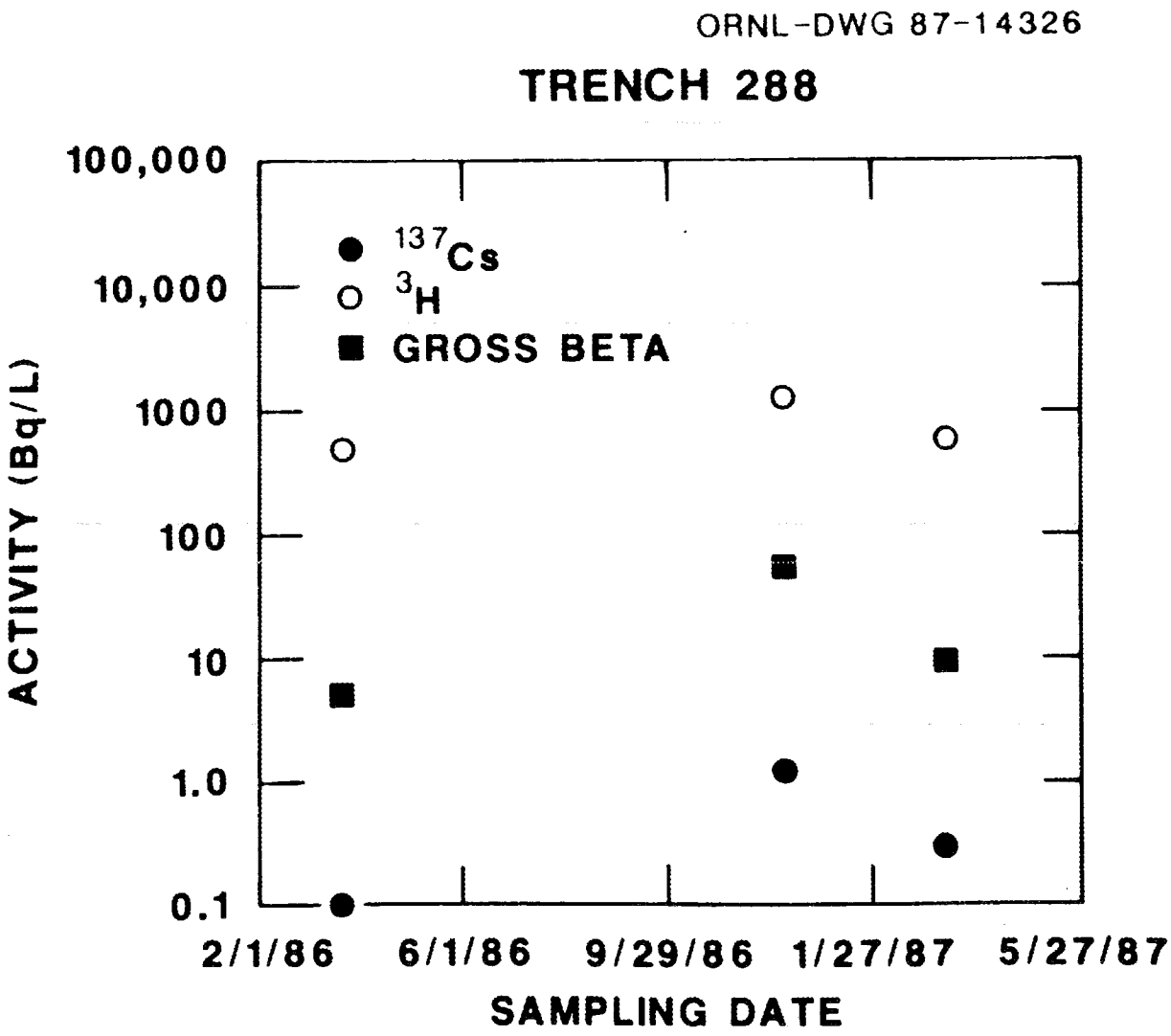

Fig. 7. Variation of ^{137}Cs, ^{3}H, and gross beta activity with time in trench 288.

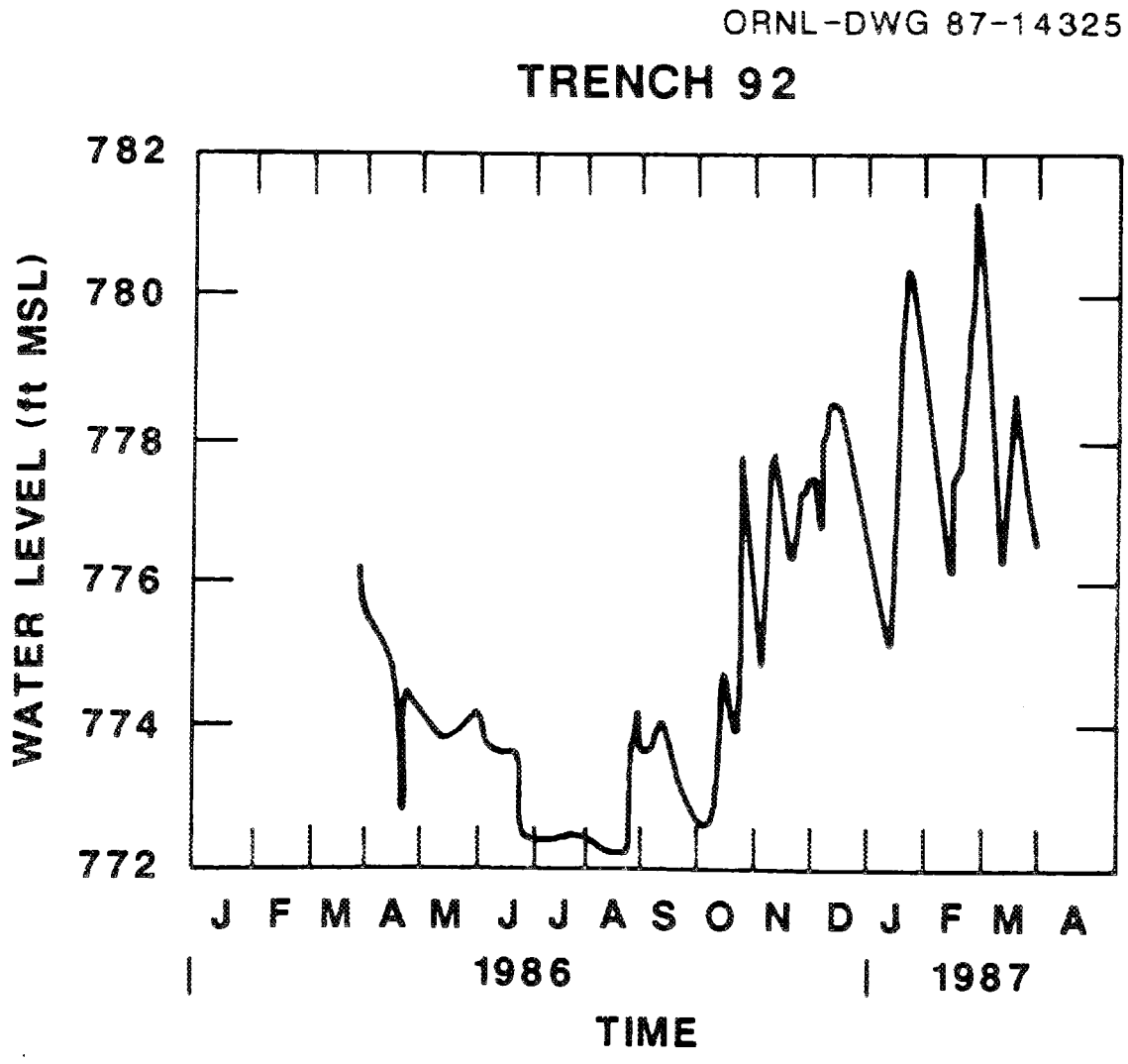

Fig. 8. Hydrograph for trench 92.

higher water level conditions. Leachate activities generally declined in trench 92; however, concentrations increased in trenches 288 and 41 in response to the increased flux of water passing through these trenches. The reason for this discordant behavior is unknown. Leachate concentrations declined in all trenches from December 1986 to March 1987 in response to lower water level conditions.

Ultimately, the source term must be described mathematically as some function of time in order to be used in hydrologic transport models. Empirical leaching models have been developed that accurately predict the release of radionuclides from the bulk waste as a function of the liquid-to-solid ratio (i.e., the ratio of leachate to mass of waste at any given point in time) on laboratory and controlled field scale leaching experiments (Francis 1986). The flux of water moving through such experiments is generally held constant at a value that is assumed to represent the average water flux at the site of interest. Although an average water flux might be definable for SWSA 6, it would be difficult to compare the instantaneous leachate concentrations described in this report, collected under various hydrologic conditions, with the results from leachate experiments conducted using a constant water flux.

The results of these experiments indicate that any effort to model leachate concentration must include consideration of the effects of trench hydrology. Although the long-term release of ^{137}Cs and ^{90}Sr may occur in accordance with the results of leaching studies conducted on a laboratory scale combined with estimates of the average water flux, a longer-term data base is necessary to statistically filter short-term variations for developing a source term model.

4.2 SATURATION STATES

The saturation state of leachate and groundwater samples with respect to a variety of common mineral phases was computed by using the geochemical program WATEQF (Plummer et al. 1983). Figure 9 shows the saturation index (the logarithm of the ion activity product divided by

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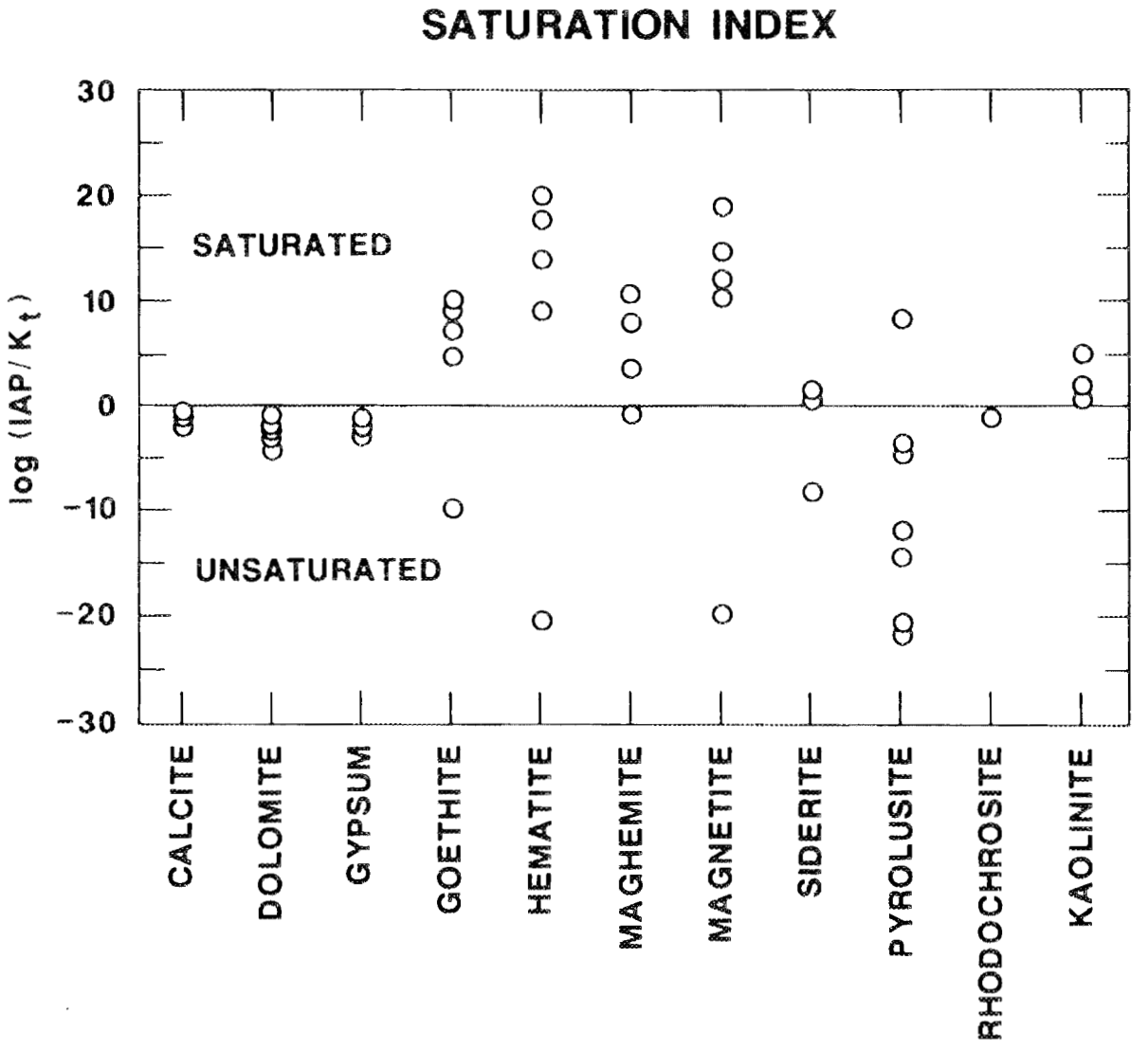

Fig. 9. Saturation index, log [ion activity product/equilibrium constant (K_t)], for trench leachate and groundwaters in SWSA 6.

the equilibrium constant) for 11 mineral phases. The phases considered include calcite ($CaCO_3$), dolomite [$CaMg(CO_3)_2$], gypsum ($CaSO_4H_2O$), goethite (FeO:OH), hematite (Fe_2O_3), magnetite (Fe_3O_4), maghemite (Fe_2O_3), siderite ($FeCO_3$), pyrolusite (MnO_2), rhodochrosite ($MnCO_3$), and kaolinite [$Al_2Si_2O_5(OH)_4$]. This comparison was performed only for the water samples for which a complete analysis, including alkalinity, had been obtained, and the total error in the charge balance for anions vs cations was less than ±10%. Eight of the samples met this criterion: T41 on 3/11/87; T260, T135, T163, and T92 on 4/22/86; S11 and T288 on 3/21/86; and 647. Thermodynamic data from Plummer et al. (1983) and the measured Eh values from Table 3 were used for computing the redox potential.

Most of the leachate samples are supersaturated with respect to the iron-bearing minerals goethite, hematite, maghemite, and magnetite; however, the groundwater samples for which the calculations were performed (S11 and 647) did not contain detectable iron and are thus unsaturated with respect to these phases. The majority of the dissolved iron was computed to be present as $Fe(OH)_2^+$. These calculations are consistent with the observation that a fine brown precipitate developed in most untreated samples if the samples were allowed to come in contact with the atmosphere. Presumably, the precipitate resulted from the oxidation of soluble Fe^{2+} species to insoluble Fe(III) compounds. Iron was very near the detection limit for all of the groundwater samples with the exception of the sample from well 650, which had a concentration of 3.6 mg/L. Since the concentration of iron in the leachate samples was as high as 69 mg/L, it appears that iron concentrations are controlled by redox conditions and precipitation reactions that may greatly affect the mobility of iron in the saturated groundwater system. If it is assumed that the soluble iron in the trench leachates resulted from the corrosion and dissolution of iron-containing wastes (e.g., steel drums), then the occurrence of iron in a groundwater sample could be considered an indicator of rapid movement of water between the bulk waste and the monitoring well and could further serve as an early warning for other

contaminants that would arrive as a result of the failure of waste containers.

Both leachate and groundwaters in SWSA 6 are generally undersaturated with respect to carbonate- and sulfate-bearing minerals. This is consistent with the premise that the concentrations of major ions such as Ca^{2+}, Mg^{2+}, HCO_3^-, and SO_4^{2-} are controlled by natural weathering processes in the soil and saprolite. Thus, the common procedure of geochemically separating groundwaters based on major ion chemistry may prove to be useful in the consideration of SWSA 6 geohydrology.

4.3 COMPARISONS OF LEACHATE RESULTS WITH ORNL WASTE INVENTORY

ORNL maintains a record of radioactive wastes disposed of in SWSA 6. Three separate modifications in the disposal reporting procedure have been made since its inception, and a detailed breakdown of radionuclides was not included until the third modification, which occurred in March 1977. Four of the leachate samples came from trenches in which a detailed breakdown of radionuclides has been documented. Figure 10 compares activities in trench leachate with the inventory activity. A likely relation would be a positive correlation between inventory activity and leachate activity. In fact, the data suggest a negative correlation between the two. It is possible that the higher-activity wastes are in a less soluble form and/or are better contained. Inclusion of the chemical waste form and containerization in future inventory reporting forms would produce a more useful inventory data base. This discordance further illustrates the need to actually measure the contaminant concentration in the leachate, rather than relying on the reported contaminant inventory.

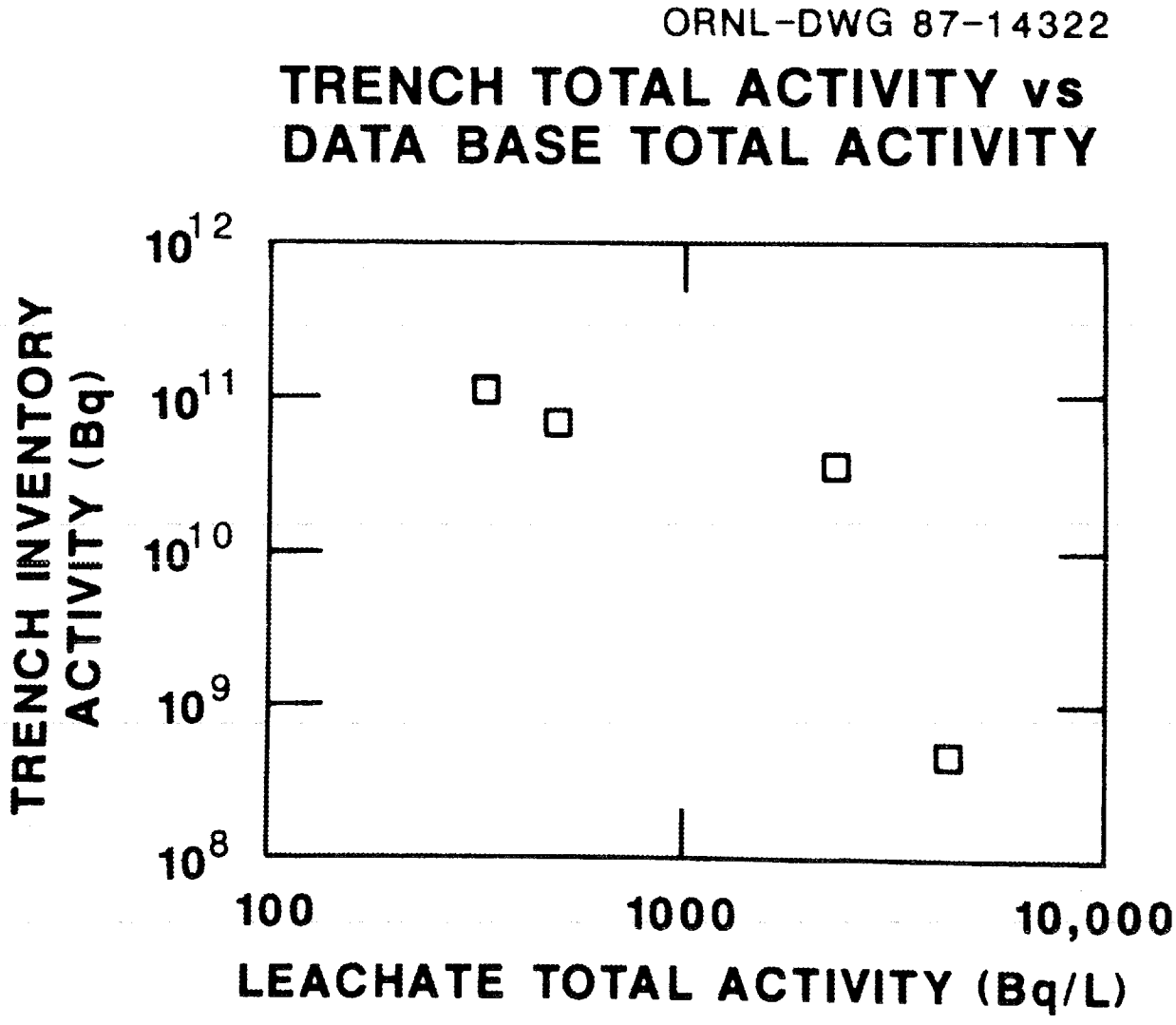

Fig. 10. Comparison of total radioactivity measured in trench leachate with the total radioactivity reported in the inventory data base.

4.4 ORGANIC COMPOUNDS

Twelve samples were collected for the determination of organic compounds. Five of these samples had organic compounds at concentrations well above the detection level; however, ten of the samples had detectable levels of at least one priority pollutant organic compound. A list of the organic compounds found in SWSA 6 is shown in Table 8. Twenty-one different EPA priority pollutant organic compounds were detected at least once in the trench leachate or groundwater samples. As discussed in Sect. 3.5, trichloroethene, benzene, tetrachloroethene, toluene, and napthalene were found at concentrations well above the analytical detection limit.

The formation of stable metal-organic complexes can significantly affect the sorption behavior and mobility of many radionuclides (McFadden 1980, Francis et al. 1980). For example, the mobility of metal-organic complexes is a major factor in the release of radioactivity from the Maxey Flats disposal site (Dayal et al. 1986), and mobilization of ^{60}Co as a Co-chelate compound has been described at ORNL (Means et al. 1978). The presence of strong chelating agents such as EDTA, NTA, and DTPA was not determined in this work. Although only very low levels of radioactivity were measured in groundwater samples that contained significant concentrations of nonchelating organic compounds, the number of groundwater samples analyzed to date is too small to assess the potential significance of increased mobility of radionuclides in SWSA 6 due to organic complexation.

Organic compounds have apparently been placed in trenches as well as in auger holes at SWSA 6. The majority of organic compounds detected are probably the result of the disposal of vials containing beta spectroscopy scintillation fluid. The contents of typical scintillation mixtures are shown in Table 9; major compounds include xylene, toluene, and benzene. All of these have been detected in SWSA 6 samples (see Table 8). Very little is known about organic contaminants in auger holes. Several groups of auger holes (a total of 37 holes) have been designated "solvent auger holes" in the historic

Table 8. Concentrations (in µg/L) of organic compounds found in SWSA 6

Compound	Well ID/sampling date					
	T92 4/22/86	T135 4/13/87	T163 4/21/87	T219 1/21/87	T257 1/21/87	T260-2 4/13/87
Chloroethane	<10	<10	49	<10	<10	<10
Methylene chloride	<2.8	<5	<5	<5	<5	<5
1,1-Dichloroethane	<4.7	<5	626	<5	<5	<5
Chloroform	<1.6	<5	<5	<5	<5	<5
1,2-Dichloroethane	<2.8	<5	<5	<5	<5	<5
1,1,2,2-Tetrachloroethene	<6.9	<5	<5	<5	<5	<5
Trichloroethene	2	<5	<5	8	<5	<5
Benzene	4.4	<5	<5	929	<5	<5
cis-1,3-Dichloropropene	<5	<5	<5	58	<5	<5
Tetrachloroethene	<4.1	<5	<5	1182	<5	<5
Toluene	<5	14	668	<5	35	<5
Ethylbenzene	<5	<5	<5	67	<5	<5
Styrene	<5	<5	<5	7	<5	<5
Total xylenes	<5	<5	<5	3696	11	<5
Phenol	<10	<10	12	<10	<10	<10
4-Methylphenol	<10	<10	91	34	<10	<10
2,4-Dimethylphenol	<10	<10	<10	<10	<10	<10
Naphthalene	51	<10	<10	354	<10	<10
bis(2-Ethylhexyl)phthalate	<10	<10	<10	<10	<10	<10
o-Cresol	<10	<10	<10	<10	<10	<10
p-Cresol	<10	<10	<10	<10	<10	<10

Table 8. (continued)

Compound	Well ID/sampling date					
	T288* 4/29/86	S11 3/17/86	647 7/10/87	648 1/21/87	649 3/11/87	650 3/11/87
Chloroethane	<10	<10	<10	<10	<10	<10
Methylene chloride	<2.8	256	<5	<5	40	<5
1,1-Dichloroethane	<4.7	<5	10	<5	<5	<5
Chloroform	<1.6	87	<1.6	85	<5	<5
1,2-Dichloroethane	<2.8	<5	<2.8	23	<5	<5
1,1,2,2-Tetrachloroethene	<6.9	<5	<6.9	55	<5	<5
Trichloroethene	<1.9	2	<1.9	2323	<5	<5
Benzene	13	<5	<4.4	70	<5	<5
cis-1,3-Dichloropropene	<5	<5	<5	<5	<5	<5
Tetrachloroethene	<4.1	<5	<5	1973	<5	<5
Toluene	1940	<5	<5	10	<5	<5
Ethylbenzene	720	<5	<5	<5	<5	<5
Styrene	<5	<5	<5	<5	<5	<5
Total xylenes	<5	<5	<5	6	<5	<5
Phenol	13	<10	<10	<10	<10	<10
4-Methylphenol	<10	<10	<10	<10	<10	<10
2,4-Dimethylphenol	32	<10	<10	<10	<10	<10
Naphthalene	1704	<10	<10	<10	<10	<10
bis(2-Ethylhexyl)phthalate	<10	13	<10	<10	<10	<10
o-Cresol	26	<10	<10	<10	<10	<10
p-Cresol	141	<10	<10	<10	<10	<10

*Original sample collected on 3/21/86. Measured concentration much greater than calibration range. Well resampled and analysis repeated.

Table 9. Organic compounds commonly found in scintillation vials and their occurrence in SWSA 6

Compound	Occurrence in SWSA 6
2,5-Diphenyloxazole	
2-Phenyl,5-(4-biphenyl)-1,3,4,oxadiazole	
Xylene	X
Toluene	X
Benzene	X
1,4-bis[2-(5-Phenyloxazolyl)]-benzene	
Hexafluorobenzene	

disposal log; however, the SWSA 6 inventory does not identify the type, amount, or containerization (if any) for the disposal. Presumably, most of these solvents came from fuel reprocessing experiments conducted at ORNL.

The presence of organic contaminants in SWSA 6 has several implications in relationship to future groundwater monitoring plans. Table 10 shows a list of selected organic compounds found in SWSA 6, along with specific gravity and solubility information. Several compounds (e.g., ethylbenzene, naphthalene, toluene, and trichloroethene) are relatively insoluble in water and, if present at sufficient concentrations, could be immiscible in groundwater. Depending on their density relative to groundwater, these compounds could be found floating on the water table surface or could sink to the bottom of a specific hydrologic unit. Examination of leachate and groundwater concentrations (see Tables 7 and 8), however, indicates that even the most concentrated samples obtained to date were undersaturated by approximately one order of magnitude. Thus, the presence of an immiscible organic phase does not seem likely in SWSA 6, and special monitoring wells capable of detecting floating or sinking contaminants probably are not warranted.

4.5 COMPARISONS WITH REGULATORY GUIDELINES

Leachate and groundwater contaminant concentration data have been compared with standards recently proposed by the EPA for facilities regulated by the Resource Conservation and Recovery Act (RCRA) (Trabalka 1987). Although standards have not been proposed for all substances, a comparison with the data from SWSA 6 is useful for placing SWSA 6 in perspective with present disposal site philosophy.

Six organic compounds occur at concentrations above the maximum proposed RCRA limit (Table 11): chloroform, benzene, tetrachloroethylene, toluene, 1,1-dichloroethylene, and 1,2-dichloroethane. Several organic compounds, which were not included in the present proposed standards, were measured at levels significantly

Table 10. Characteristics of organic compounds found in SWSA 6

Compound	Specific gravity[a]	Solubility[b] (mg/L at 25°C)
Benzene	0.88^{15}	1,780
Chloroform	1.49^{16}	9,300
Ethylbenzene	0.87^{20}	152
Methylene chloride	1.33^{15}	16,700
Naphthalene	1.15^{20}	31.7[c]
Toluene	0.87^{20}	515
Trichloroethene	1.47^{15}	1,100
1,1-Dichloroethane	1.23^{20}	5,500
m-Xylene	0.87^{15}	196[d]
p-Xylene	0.85^{28}	198[d]

[a]Merck Index. Superscripts indicate measurement temperature in °C. Data are relative to the density of water at 4°C.
[b]Verschueren 1983.
[c]May and Wasik 1978.
[d]Stephen and Stepbken 1963.

Table 11. Comparison of concentrations of organic compounds with proposed RCRA limits (Trabalka 1987)

Contaminant	Limit	Units	Well ID/sampling date			
			T41 12/4/86	T92 12/4/86	T135 4/13/87	T163 4/21/87
Acrylonitrile	2	µg/L	NA	NA	NA	NA
Arsenic	0.05	mg/L	<0.10	<0.10	<0.010	<0.010
Barium	1	mg/L	0.14	0.21	0.16	0.061
Benzene	5	µg/L	NA	4.4	<5	<5
bis(2-Chlorethyl)ether	0.3	µg/L	NA	<10	<10	<10
Cadmium	0.01	mg/L	<0.005	<0.005	0.004	0.0016
Carbon disulfide	1000	µg/L	NA	<5	<5	<5
Carbon tetrachloride	5	µg/L	NA	<2.8	<5	<5
Chlordane	2	µg/L	NA	<10	<10	<10
Chlorobenzene	100	µg/L	NA	<5	<5	<5
Chloroform	5	µg/L	NA	<1.6	<5	<5
Chromium	0.05	mg/L	<0.040	<0.040	<0.0040	<0.0040
o-Cresol	700	µg/L	NA	<10	<10	<10
m-Cresol	700	µg/L	NA	NA	NA	NA
p-Cresol	700	µg/L	NA	<10	<10	<10
2,4-D	100	µg/L	NA	NA	NA	NA
1,2-Dichlorobenzene	300	µg/L	NA	<10	<10	<10
1,4-Dichlorobenzene	750	µg/L	NA	<10	<10	<10
1,2-Dichloroethane	5	µg/L	NA	<2.8	<5	<5
1,1-Dichloroethylene	7	µg/L	NA	<2.8	<5	<5
2,4-Dinitrotoluene	1	µg/L	NA	<10	<10	<10
Endrin	0.2	µg/L	NA	<10	<10	<10
Heptachlor	0.1	µg/L	NA	<10	<10	<10
Hexachlorobenzene	0.2	µg/L	NA	<10	<10	<10
Hexachlorobutadiene	50	µg/L	NA	<10	<10	<10
Hexachloroethane	300	µg/L	NA	<10	<10	<10
Isobutanol	2500	µg/L	NA	NA	NA	NA
Lead	0.05	mg/L	<0.200	<0.20	<0.020	<0.020
Lindane	4	µg/L	NA	<10	<10	<10
Mercury	0.002	mg/L	NA	NA	<0.0001	<0.0001
Methoxychlor	100	µg/L	NA	NA	NA	NA
Methylene chloride	600	µg/L	NA	<2.8	<5	<5
Methyl ethyl ketone	500	µg/L	NA	NA	NA	NA
Nickel	0.15	mg/L	0.27	<0.06	<0.0120	<0.006
Nitrobenzene	4	µg/L	NA	<10	<10	<10
Pentachlorophenol	250	µg/L	NA	<50	<50	<50
Phenol	1000	µg/L	NA	<10	<10	12
Pyridine	30	µg/L	NA	NA	NA	NA
Selenium	0.01	mg/L	<0.20	<0.20	<0.020	<0.020
Silver	0.05	mg/L	<0.050	<0.050	<0.005	<0.005
1,1,1,2-Tetrachloroethane	700	µg/L	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	20	µg/L	NA	<6.9	<5	<5
Tetrachloroethylene	7	µg/L	NA	<4.1	<5	<5

Table 11. (continued)

Contaminant	Limit	Units	Well ID/sampling date			
			T41 12/4/86	T92 12/4/86	T135 4/13/87	T163 4/21/87
2,3,4,6-Tetrachlorophenol	100	µg/L	NA	NA	NA	NA
Thallium	0.002	mg/L	NA	NA	NA	NA
Toluene	1000	µg/L	NA	<5	14	668
Toxaphene	5	µg/L	NA	NA	NA	NA
1,1,1-Trichloroethane	200	µg/L	NA	<3.8	<5	<6
1,1,2-Trichloroethane	60	µg/L	NA	<5	<5	<5
Trichloroethylene	5	µg/L	NA	2	<5	<5
2,4,5-Trichlorophenol	400	µg/L	NA	<10	<50	<50
2,4,6-Trichlorophenol	20	µg/L	NA	<10	<10	<10
2,4,5-TP (Silvex)	10	µg/L	NA	NA	NA	NA
Vinyl chloride	1	µg/L	NA	<10	<5	<5
H-3	3300	Bq/L	340,000±10,000	2600±100	33,000±1000	620±50
C-14	110	Bq/L	NA	NA	2600±100	32±21
Na-22	19	Bq/L	NA	NA	NA	NA
Fe-55	370	Bq/L	NA	NA	NA	NA
Co-60	7.4	Bq/L	<0.6	<0.3	0.70±0.22	0.33±0.18
Sr-90	1.9	Bq/L	3100±100	0.84±.20	NA	NA
Zr-93	370	Bq/L	NA	NA	NA	NA
Tc-99	190	Bq/L	<100	<100	<100	<100
Ru-106	11	Bq/L	NA	NA	NA	NA
Sb-125	150	Bq/L	NA	NA	NA	NA
I-129	3.7	Bq/L	NA	NA	NA	NA
Cs-134	3.0	Bq/L	NA	NA	NA	NA
Cs-137	3.7	Bq/L	130±10	0.33±0.28	40±1	2.4±0.2
Sm-151	1100	Bq/L	NA	NA	NA	NA
Eu-152	74	Bq/L	NA	NA	NA	NA
Eu-154	37	Bq/L	NA	NA	NA	NA
Eu-155	260	Bq/L	NA	NA	NA	NA
Ra-226	0.15*	Bq/L	NA	NA	NA	NA
Ra-228	0.15*	Bq/L	NA	NA	NA	NA
Th-230	0.44*	Bq/L	NA	NA	NA	NA
Th-232	0.074*	Bq/L	NA	NA	NA	NA
U-234	0.74*	Bq/L	NA	NA	NA	NA
U-238	0.89	Bq/L	NA	NA	NA	NA
Pu-239	1.5	Bq/L	NA	NA	NA	NA
Am-241	0.15	Bq/L	NA	NA	NA	NA

Table 11. (continued)

Contaminant	Limit	Units	Well ID/sampling date			
			T219 1/21/87	T257 12/5/86	T260-2 4/13/87	T288 12/5/86
Acrylonitrile	2	µg/L	NA	NA	NA	NA
Arsenic	0.05	mg/L	<0.060	<0.10	<0.010	<0.10
Barium	1.0	mg/L	0.1	<0.099	0.13	0.28
Benzene	5	µg/L	929	<5	<5	13
bis(2-Chlorethyl)ether	0.3	µg/L	<10	<10	<10	<10
Cadmium	0.01	mg/L	<0.003	<0.005	0.0033	<0.005
Carbon disulfide	1000	µg/L	<5	<5	<5	<5
Carbon tetrachloride	5	µg/L	<5	<5	<5	<2.6
Chlordane	2	µg/L	<10	<10	<10	<10
Chlorobenzene	100	µg/L	<5	<5	<5	<5
Chloroform	5	µg/L	<5	<5	<5	<1.6
Chromium	0.05	mg/L	<0.024	<0.040	<0.0040	<0.040
o-Cresol	700	µg/L	<10	<10	<10	26
m-Cresol	700	µg/L	NA	NA	NA	NA
p-Cresol	700	µg/L	<10	<10	<10	141
2,4-D	100	µg/L	NA	NA	NA	NA
1,2-Dichlorobenzene	300	µg/L	<10	<10	<10	<10
1,4-Dichlorobenzene	750	µg/L	<10	<10	<10	<10
1,2-Dichloroethane	5	µg/L	<5	<5	<5	<2.8
1,1-Dichloroethylene	7	µg/L	<5	<5	<5	<2.8
2,4-Dinitrotoluene	1	µg/L	<10	<10	<10	<10
Endrin	0.2	µg/L	<10	<10	<10	<10
Heptachlor	0.1	µg/L	<10	<10	<10	<10
Hexachlorobenzene	0.2	µg/L	<10	<10	<10	<10
Hexachlorobutadiene	50	µg/L	<10	<10	<10	<10
Hexachloroethane	300	µg/L	<10	<10	<10	<10
Isobutanol	2500	µg/L	NA	NA	NA	NA
Lead	0.05	mg/L	<0.120	<0.20	<0.020	<0.20
Lindane	4	µg/L	<10	<10	<10	<10
Mercury	0.002	mg/L	<0.0002	NA	<0.0001	NA
Methoxychlor	100	µg/L	NA	NA	NA	NA
Methylene chloride	600	µg/L	<5	<5	<5	<2.8
Methyl ethyl ketone	500	µg/L	NA	NA	NA	NA
Nickel	0.15	mg/L	<0.036	<0.06	<0.0060	<0.06
Nitrobenzene	4	µg/L	<10	<10	<10	<10
Pentachlorophenol	250	µg/L	<50	<50	<50	<50
Phenol	1000	µg/L	<10	<10	<10	13
Pyridine	30	µg/L	NA	NA	NA	NA
Selenium	0.01	mg/L	<0.120	<0.20	<0.020	<0.20
Silver	0.05	mg/L	<0.030	<0.050	<0.005	<0.050
1,1,1,2-Tetrachloroethane	700	µg/L	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	20	µg/L	<5	<5	<5	<6.9
Tetrachloroethylene	7	µg/L	1182	<5	<5	<4.1

Table 11. (continued)

Contaminant	Limit	Units	Well ID/sampling date			
			T219 1/21/87	T257 12/5/86	T260-2 4/13/87	T288 12/5/86
2,3,4,6-Tetrachlorophenol	100	µg/L	NA	NA	NA	NA
Thallium	0.002	mg/L	NA	NA	NA	NA
Toluene	1000	µg/L	<5	35	<5	1940
Toxaphene	5	µg/L	NA	NA	NA	NA
1,1,1-Trichloroethane	200	µg/L	<5	<5	<5	<2.8
1,1,2-Trichloroethane	60	µg/L	<5	<5	<5	<5
Trichloroethylene	5	µg/L	8	<5	<5	<1.9
2,4,5-Trichlorophenol	400	µg/L	<50	<50	<50	<10
2,4,6-Trichlorophenol	20	µg/L	<10	<10	<10	<10
2,4,5-TP (Silvex)	10	µg/L	NA	NA	NA	NA
Vinyl chloride	1	µg/L	<10	<10	<5	<10
H-3	3300	Bq/L	380±40	23,000±1000	310±40	1200±100
C-14	110	Bq/L	30±20	NA	19±20	NA
Na-22	19	Bq/L	NA	NA	NA	NA
Fe-55	370	Bq/L	NA	NA	NA	NA
Co-60	7.4	Bq/L	<2.0	<0.3	<0.2	0.43±0.29
Sr-90	1.9	Bq/L	NA	0.26±0.13	NA	12±1
Zr-93	370	Bq/L	NA	NA	NA	NA
Tc-99	190	Bq/L	<100	<100	<100	<100
Ru-106	11	Bq/L	NA	NA	NA	NA
Sb-125	150	Bq/L	NA	NA	NA	NA
I-129	3.7	Bq/L	NA	NA	NA	NA
Cs-134	3.0	Bq/L	NA	NA	NA	NA
Cs-137	3.7	Bq/L	3±0.4	<0.3	<0.3	1.2±0.3
Sm-151	1100	Bq/L	NA	NA	NA	NA
Eu-152	74	Bq/L	NA	NA	NA	NA
Eu-154	37	Bq/L	NA	NA	NA	NA
Eu-155	260	Bq/L	NA	NA	NA	NA
Ra-226	0.15*	Bq/L	NA	NA	NA	NA
Ra-228	0.15*	Bq/L	NA	NA	NA	NA
Th-230	0.44*	Bq/L	NA	NA	NA	NA
Th-232	0.074*	Bq/L	NA	NA	NA	NA
U-234	0.74*	Bq/L	NA	NA	NA	NA
U-238	0.89	Bq/L	NA	NA	NA	NA
Pu-239	1.5	Bq/L	NA	NA	NA	NA
Am-241	0.15	Bq/L	NA	NA	NA	NA

Table 11. (continued)

Contaminant	Limit	Units	Well ID/sampling date				
			S11 3/17/86	647 7/10/86	648 1/21/87	649 3/11/87	650 3/11/87
Acrylonitrile	2	µg/L	NA	NA	NA	NA	NA
Arsenic	0.05	mg/L	<0.100	<0.100	<0.010	<0.100	<0.100
Barium	1	mg/L	0.16	0.12	0.2	1.2	2
Benzene	5	µg/L	<5	<4.4	70	<5	<5
bis(2-Chlorethyl)ether	0.3	µg/L	<10	<10	<10	<10	<10
Cadmium	0.01	mg/L	<0.005	<0.005	<0.0005	<0.026	<0.0005
Carbon disulfide	1000	µg/L	<5	<5	<5	<5	<5
Carbon tetrachloride	5	µg/L	<5	<2.8	<5	<5	<5
Chlordane	2	µg/L	<10	<10	<10	<10	<10
Chlorobenzene	100	µg/L	<5	<5	<5	<5	<5
Chloroform	5	µg/L	87	<1.6	85	<5	<5
Chromium	0.05	mg/L	<0.040	<0.040	0.0052	<0.042	<0.045
o-Cresol	700	µg/L	<10	<10	<10	<10	<10
m-Cresol	700	µg/L	NA	NA	NA	NA	NA
p-Cresol	700	µg/L	<10	<10	<10	<10	<10
2,4-D	100	µg/L	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	300	µg/L	<10	<10	<10	<10	<10
1,4-Dichlorobenzene	750	µg/L	<10	<10	<10	<10	<10
1,2-Dichloroethane	5	µg/L	<5	<2.8	23	<5	<5
1,1-Dichloroethylene	7	µg/L	<5	<2.8	11	<5	<5
2,4-Dinitrotoluene	1	µg/L	<10	<10	<10	<10	<10
Endrin	0.2	µg/L	<10	<10	<10	<10	<10
Heptachlor	0.1	µg/L	<10	<10	<10	<10	<10
Hexachlorobenzene	0.2	µg/L	<10	<10	<10	<10	<10
Hexachlorobutadiene	50	µg/L	<10	<10	<10	<10	<10
Hexachloroethane	300	µg/L	<10	<10	<10	<10	<10
Isobutanol	2500	µg/L	NA	NA	NA	NA	NA
Lead	0.05	mg/L	<0.200	<0.200	<0.020	<0.200	<0.200
Lindane	4	µg/L	<10	<10	<10	<10	<10
Mercury	0.002	mg/L	<0.0001	0.0007	<0.0002	<0.0001	<0.0002
Methoxychlor	100	µg/L	NA	NA	NA	NA	NA
Methylene chloride	600	µg/L	256	<5	<5	40	<5
Methyl ethyl ketone	500	µg/L	NA	NA	NA	NA	NA
Nickel	0.15	mg/L	0.06	0.06	<0.006	<0.060	<0.060
Nitrobenzene	4	µg/L	<10	<10	<10	<10	<10
Pentachlorophenol	250	µg/L	<50	<50	<50	<50	<50
Phenol	1000	µg/L	<10	<10	<10	<10	<10
Pyridine	30	µg/L	NA	NA	NA	NA	NA
Selenium	0.01	mg/L	<0.200	<0.200	<0.020	<0.200	<0.200
Silver	0.05	mg/L	<0.050	<0.050	<0.005	<0.050	<0.050
1,1,1,2-Tetrachloroethane	700	µg/L	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	20	µg/L	<5	<6.9	55	<5	<5
Tetrachloroethylene	7	µg/L	<5	<5	1973	<5	<5

Table 11. (continued)

Contaminant	Limit	Units	Well ID/sampling date				
			S11 3/17/86	647 7/10/86	648 1/21/87	649 3/11/87	650 3/11/87
2,3,4,6-Tetrachlorophenol	100	µg/L	NA	NA	NA	NA	NA
Thallium	0.002	mg/L	NA	NA	NA	NA	NA
Toluene	1000	µg/L	<5	<5	10	<5	<5
Toxaphene	5	µg/L	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	200	µg/L	<5	<3.8	<5	<5	<5
1,1,2-Trichloroethane	60	µg/L	<5	<5	22	<5	<5
Trichloroethylene	5	µg/L	2	<1.9	2323	<5	<5
2,4,5-Trichlorophenol	400	µg/L	<10	<10	<50	<50	<50
2,4,6-Trichlorophenol	20	µg/L	<10	<10	<10	<10	<10
2,4,5-TP (Silvex)	10	µg/L	NA	NA	NA	NA	NA
Vinyl chloride	1	µg/L	<10	<10	<10	<10	<10
H-3	3300	Bq/L	3700±200	34±21	71±24	15±20	26,000±1000
C-14	110	Bq/L	48±36	8±18	25±20	<20	13±14
Na-22	19	Bq/L	NA	NA	NA	NA	NA
Fe-55	390	Bq/L	NA	NA	NA	NA	NA
Co-60	7.4	Bq/L	0.87±0.33	<0.1	<3.0	<0.5	<0.1
Sr-90	1.9	Bq/L	NA	NA	NA	NA	NA
Zr-93	370	Bq/L	NA	NA	NA	NA	NA
Tc-99	190	Bq/L	<100	<100	<100	<100	<100
Ru-106	11	Bq/L	NA	NA	NA	NA	NA
Sb-125	150	Bq/L	NA	NA	NA	NA	NA
I-129	3.7	Bq/L	NA	NA	NA	NA	NA
Cs-134	3.0	Bq/L	NA	NA	NA	NA	NA
Cs-137	3.7	Bq/L	<0.1	<0.1	<0.3	<0.4	<0.1
Sm-151	1100	Bq/L	NA	NA	NA	NA	NA
Eu-152	74	Bq/L	NA	NA	NA	NA	NA
Eu-154	37	Bq/L	NA	NA	NA	NA	NA
Eu-155	260	Bq/L	NA	NA	NA	NA	NA
Ra-226	0.15*	Bq/L	NA	NA	NA	NA	NA
Ra-228	0.15*	Bq/L	NA	NA	NA	NA	NA
Th-230	0.44*	Bq/L	NA	NA	NA	NA	NA
Th-232	0.74*	Bq/L	NA	NA	NA	NA	NA
U-234	0.74*	Bq/L	NA	NA	NA	NA	NA
U-238	0.89*	Bq/L	NA	NA	NA	NA	NA
Pu-239	1.5	Bq/L	NA	NA	NA	NA	NA
Am-241	0.15	Bq/L	NA	NA	NA	NA	NA

*Four percent of value from U.S. DOE order 5480.XX (Radiation Protection of the Public and the Environment; March 31, 1989, draft), Table 1, Column 2. Four percent of the value was used in order to compare the U.S. DOE Standards based on an exposure of 100 mrem/yr with the proposed EPA Standard based on an exposure of 4 mrem/yr.

greater than the detection limits. These include chloroethane, 1,1-dichloroethane, cis-1,3-dichloropropene, ethylbenzene, total xylenes, 4-methylphenol, 2,4-dimethylphenol, napthalene, and p-cresol. Although the concentrations of organic compounds included in the proposed RCRA standards were exceeded by only 4 of the 12 samples, organic compounds significantly greater than the detection level were measured in 7 of the 12 samples.

Barium and nickel concentrations exceeded the proposed limits by as much as a factor of 2. The detection limit for Pb, As, and Se measured by the ICP method were not always below the proposed RCRA limit.

^{3}H, ^{14}C, and ^{137}Cs were measured at concentrations greater than the proposed RCRA limit. Although gross alpha and gross beta activities are not included in the proposed RCRA standards, the National Primary Drinking Water Standards (NPDWS) for gross alpha and gross beta activity of 0.55 Bq/L and 0.29 Bq/L are useful for comparative purposes.

Gross alpha activity was measured at 100 $\pm$ 45 Bq/L in one sample; however, the majority of samples were near the analytical detection limit of about 1 Bq/L. Gross beta activity was detectable in all of the leachate samples, and a maximum of 18,000 Bq/L was measured in one sample. (It should be noted that the gross beta analysis does not detect ^{3}H and is primarily an analysis for ^{90}Sr or other radionuclides having similar high-energy beta particles.) Gross beta activity was near the detection limit of about 2 Bq/L in all of the groundwater samples. The standard gross alpha and gross beta analyses are not sensitive enough to reach the low levels specified by the NPDWS limits, and additional work would be needed to ascertain if samples at or near the analytical detection limit actually met this limit.

5. RECOMMENDATIONS

Based on the results and experience obtained to date, several recommendations are made with respect to future trench leachate and groundwater sampling and analysis activities in SWSA 6.

1. Samples should be collected from unsaturated trenches and from near unsaturated auger holes to explore the portion of the source term that may be migrating into the unsaturated zone. Since approximately 90% of the trenches and all of the auger holes are probably unsaturated for a significant portion of the year, a large fraction of the total contaminant source term is likely to occur under unsaturated conditions. The significance of this portion of the source term has not been explored because all samples obtained to date were collected under saturated conditions. New sampling techniques must be proven for collection from unsaturated lysimeters.

2. Leachate and groundwater samples should be collected and analyzed for organic chelating agents such as EDTA, NTA, and DTPA. This activity is particularly important in order to study the possibility of enhanced contaminant mobility due to the formation of radionuclide- and metal-chelate complexes; such complexes typically have high solubility in water and are poorly sorbed onto soil components. Sampling should be concentrated in the region of SWSA 6 where, according to the historic log, "solvent" and "high-activity" auger holes have been intermixed.

3. Selected representative trenches, both saturated and unsaturated, should be sampled repeatedly during wet and dry periods to help establish an empirical source term model that includes the effects of local trench hydrology. A long-term program spanning at least 3 to 5 years and including hydrologic monitoring to define an average water flux is critically needed.

4. A soil-gas survey should be performed to attempt to define the extent of organic contamination. The majority of organic contaminants detected in SWSA 6 are relatively volatile. As a result of this volatility, organic vapors diffusing upward could probably be detected

by sampling soil gas via shallow monitoring probes. This technique is becoming routine at many hazardous waste sites and provides a rapid, inexpensive means for defining the areal extent of volatile organic contamination.

5. The chemical form and containerization of wastes should be included in future inventory reporting forms.

6. SUMMARY

This report summarizes the results of the groundwater and trench leachate sampling and analysis activities conducted in SWSA 6 during FY 1986 and FY 1987. Water samples were analyzed both for the concentration of contaminants (radionuclides, EPA priority pollutant organic compounds, Superfund site organic compounds, hazardous inorganic elements, and other chemicals) and for water quality parameters and components. The purpose of this work is to obtain contaminant and groundwater quality information that can be applied to the development of contaminant source terms.

The SWSA 6 disposal site has been receiving low-level wastes since 1968. Wastes have been emplaced in the soil by shallow-landfill methodology via trenches and auger holes. Only limited information on the identity or quantity of radionuclides emplaced is available from the SWSA 6 historic operational log. In addition to radionuclides, organic and metal contaminants are known to be present in SWSA 6, but no information on these materials was included in the log. Waste containerization varied from no containerization to the use of concrete boxes, glass bottles, or steel cans; again, historic documentation is nonexistent. The limited information available makes prediction of contaminant release rates problematic, if not impossible, from existing inventory data. Therefore, we are using a sampling approach to establish the source term.

Water was withdrawn from the wells using either positive displacement, 100% Teflon bladder pumps or peristaltic pumps fitted with Teflon tubing down the well and Tygon tubing around the pump head. A number of field parameters were measured either as the sample was withdrawn or promptly after collection in the field. (Field parameters might be expected to change if the water were allowed to stand or were exposed to air.) The field parameters measured were temperature, acidity (pH), DO, redox potential (Eh), and conductivity. Alkalinity titrations were initially done in the field but were subsequently performed in the laboratory within 24 h after the sample

was obtained. Several sample splits were obtained and appropriately stabilized and/or bottled for transport to the ACD for subsequent analyses. The ACD performed analyses for the following: (1) alpha-, beta-, and gamma-emitting radionuclides (using appropriate radiochemical counting techniques, including chemical separation steps where necessary); (2) cations, including hazardous metals (using ICP or AA techniques); (3) anions (using ion chromatography); (4) EPA priority pollutants (using GC-MS methods); and (5) chemicals such as carbon, ammonia, etc (using miscellaneous types of analyses). Completion of all these analyses for each water sample represented an appreciable effort and cost.

Because transport of contaminants in the unsaturated zone of SWSA 6 could be a significant source term component, commercially available apparatus for sampling groundwater under unsaturated conditions were obtained and tested. Although operational, the time required to obtain the minimum 2-L sample volume needed for the analyses would be prohibitive, and no unsaturated zone samples were collected during this report period. A custom unsaturated lysimeter sampler has been designed and is being fabricated. It will be tested in the future.

The field analyses of groundwater and trench leachate samples showed similar compositions. Acidity ranges from pH 5.7 to 8.0; temperature, from 10.5 to 25.5°C; and alkalinity, from 2.5 to 14.4 m$\underline{M}$ HCO_3^-. The DO and Eh measurements showed generally oxidizing redox condition. Higher DO values correlated with higher Eh values. Conductivity values were low, with the exception of one trench that had been used previously in a salt injection test. In general, all field analytical results were typical of values for shallow groundwaters in eastern Tennessee. As might be expected, the more extreme (highest or lowest) values were measured for samples from trenches, where waste components could contribute to or alter the groundwater composition.

The cation and anion analyses of trench leachate and groundwater samples also showed results typical of shallow groundwaters. Calcium, magnesium, and sodium were the major cations; bicarbonate, sulfate, and

chloride were the major anions. Trench leachates were generally enriched in chloride compared with groundwater samples.

Only a few hazardous metal elements were identified in groundwater or trench leachate samples. Nickel was detected in several samples in concentrations as high as 0.27 mg/L, and mercury was detected in one groundwater sample (but not in any of the trench leachate samples) at a low concentration of 0.0007 mg/L.

Because SWSA 6 is a radioactive waste disposal site, a number of radionuclides were present in both trench leachates and groundwater samples. Tritium was ubiquitous in SWSA 6 samples. Concentrations as high as 340,000 $\pm$ 10,000 Bq/L were measured in one trench leachate. Tritium concentrations exceeded 1000 Bq/L in 11 of the 16 trench leachate samples and in 2 of the 5 groundwater samples. Strontium-90 and ^{14}C were present at appreciable concentrations in a number of trench leachate samples, but concentrations were lower or the isotopes were absent in groundwater samples. The highest ^{90}Sr value observed was 3600 $\pm$ 100 Bq/L; the highest ^{14}C value was 2900 $\pm$ 100 Bq/L. Low levels of ^{137}Cs were detected in a few trench leachate samples. Cobalt-60 and total radium values were at or near the analytical detection limit in all samples. Uranium or thorium radionuclides were not identified in any sample.

A graphic comparison of the ^{3}H, ^{60}Co, and ^{90}Sr concentrations in each trench leachate and groundwater sample was completed. As might be expected considering the heterogeneous nature of the wastes and waste containerization in the trenches, no correlation was observed. This finding, however, suggests that future monitoring of SWSA 6 groundwater contamination may have to include a complete radiochemical analysis rather than rely on monitoring of a few key or indicator radionuclides.

A total of 21 EPA priority pollutant organic compounds was identified in groundwater or trench leachate samples. Because most of the samples were collected from stainless-steel-cased wells, few, if any, of the organics detected are believed to have been present as a result of well installation operations. While caution should be used

in considering the significance of ppb levels of priority pollutant compounds that are near the analytical detection limit, several organics were present at high concentrations (up to about 1 mg/L, 100 to 500 times the analytical detection limit). The priority pollutants present at relatively high concentrations were benzene, naphthalene, tetrachloroethene, toluene, and trichloroethene.

Naphthalene, tetrachloroethene, and toluene were detected at high concentrations in more than one well. High concentrations of priority pollutants were found in both trench leachate and groundwater samples. Several organics were present at concentrations that exceeded the proposed RCRA site guidelines: chloroform, benzene, tetrachloroethylene, toluene, 1,1-dichloroethylene, and 1,2-dichloroethanechloroform.

The presence of organic contaminants in SWSA 6 has several implications for groundwater monitoring plans. Organic compounds have apparently been placed in both trenches and auger holes. Beta spectroscopy scintillation fluids and degreasing compounds may represent the principal organics present in trenches. Xylene, toluene, and benzene are typical components of scintillation fluids, and all of these have been observed in various water samples. Chlorohydrocarbons are frequently used in metal cleaning steps, and such compounds have also been observed in various samples. No information is available concerning the organics discharged to the 37 auger holes identified as solvent auger holes. Future SWSA 6 monitoring plans should include adequate procedures to detect mobile organic compounds in the vicinity of the solvent auger holes. None of the organics identified in this study were at concentrations near to or above saturation in water. Thus, the present work does not indicate a need for special wells capable of sampling floating or sinking water-immiscible contaminants.

In order to explore the variation in contaminant concentration with time, four trenches were sampled on three separate dates over a 15-month period. Large variations (factors tenfold to 100-fold) were observed in the concentrations of ^{3}H, ^{90}Sr, and ^{137}Cs. Although the radionuclide concentrations showed a weak correlation with trench hydrology (wet vs dry conditions), it may be difficult to predict the contaminant

response to changes in infiltration, etc., because discordant changes were measured. For example, ^{90}Sr or ^{137}Cs concentrations were observed to increase in some cases while ^{3}H concentrations decreased, or vise versa. A better understanding of trench hydrology and of waste leaching or dissolution processes may be necessary to rationalize such observations.

The saturation state of trench leachates and groundwaters was modeled with the geochemical code WATEQF with respect to a variety of common mineral phases. Most of the trench leachate samples were computed to be supersaturated with respect to the iron-bearing minerals goethite, hematite, maghemite, and magnetite. Iron concentrations were much lower in groundwater samples. This observation suggests that iron in the trench leachates could be the result of corrosion and dissolution of waste components such as iron or steel parts, cans, etc. If so, then the appearance of high concentrations of dissolved iron in site groundwaters might be useful as an indication of rapid movement of water from a trench to a nearby monitoring well.

The total radionuclide activity in four trench leachates was compared with the existing radionuclide inventory data for those trenches. A direct relationship might be expected (i.e., the trenches with the higher inventory should have the leachates with the higher activities). Such a relationship was not observed in the cases of the four trenches examined. In fact, an inverse relationship was seen; the trenches with the highest inventory had the lowest leachate activities, and vise versa. The inverse relationship may be an artifact of the small number of trenches sampled; a larger sample population might have shown simply a random relationship. The limited data obtained to date suggest that the SWSA 6 radionuclide inventory information may be of little value in attempting to estimate trench leachate radionuclide concentrations. Such a conclusion may not be inconsistent with the known heterogeneity of waste materials and containerization. This observation helps underscore the need for experimental measurement of contaminant concentrations and illuminates the difficulties that may be encountered in attempting to predict future site contaminant release rates.

For purposes of comparison with current regulatory philosophy, the trench leachate and groundwater contaminant data were compared with the proposed EPA RCRA guidelines. Six organic compounds and two hazardous inorganic elements were present at concentrations near or substantially above the proposed limit. Because SWSA 6 is a radioactive waste disposal site, a number of radionuclides exceeded the proposed RCRA limits. Of these, ^{3}H was the worst offender.

Recommended future activities in SWSA 6 include (1) development of methodology for sampling in the unsaturated zone and estimation of the fraction of contaminant source terms that may be represented by transport in the unsaturated zone, (2) analysis for organic chelating agents to explore the potential for mobilization of radionuclides or metal elements as soluble complexes, (3) a long-term (3- to 5-year) study of selected trenches with repeated sampling during wet and dry seasons to help define the influence of trench hydrology on the source terms, and (4) a soil-gas survey to help define the areal extent of organic contamination.

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