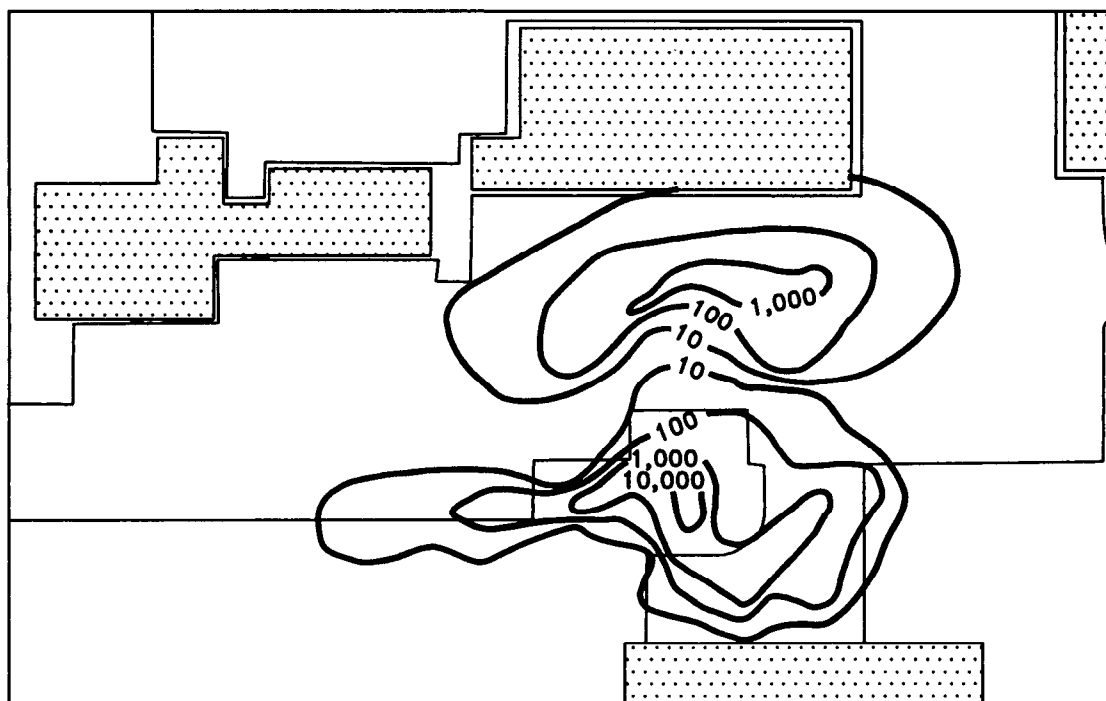
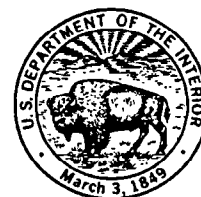


# DELINEATION OF GROUND-WATER CONTAMINATION USING SOIL-GAS ANALYSES NEAR JACKSON, TENNESSEE



Prepared by the  
U.S. GEOLOGICAL SURVEY

in cooperation with the  
CITY OF JACKSON, TENNESSEE,  
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**By Roger W. Lee**

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**U.S. GEOLOGICAL SURVEY**

**Water-Resources Investigations Report 90-4137**

**Prepared in cooperation with the  
CITY OF JACKSON, TENNESSEE,  
JACKSON UTILITY DIVISION**



**Nashville, Tennessee  
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**DEPARTMENT OF THE INTERIOR**

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**U.S. GEOLOGICAL SURVEY**

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## CONVERSION FACTORS

Multiply	By	To obtain metric units
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
gallon (gal)	3.785	liter (L)
	$3.785 \times 10^{-3}$	cubic meter (m <sup>3</sup> )

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:  
 $^{\circ}\text{F} = 1.8 ^{\circ}\text{C} + 32$

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# DELINEATION OF GROUND-WATER CONTAMINATION USING SOIL-GAS ANALYSES NEAR JACKSON, TENNESSEE

by Roger W. Lee

## ABSTRACT

*An investigation of the ground-water resources near Jackson, West Tennessee, was conducted during 1988-89. The study included determination of the occurrence of contaminants in the shallow aquifer using soil-gas analyses in the unsaturated zone. Between 1980 and 1988, an underground fuel-storage tank leaked about 3,000 gallons of unleaded fuel to the water table about 4 feet below land surface. A survey of soil gas using a gas chromatograph equipped with a photoionization detector showed concentrations of volatile organic compounds greater than 10,000 parts per million near the leak. These compounds were detected in an area about 240 feet long and 110 feet wide extending west from the point source. The chromatograms provided two distinct "fingerprints" of volatile organic compounds. The first revealed the presence of benzene, toluene, and xylenes, which are constituents of unleaded fuel, in addition to other volatile compounds, in soil gas in the area near the leak. The second did not reveal any detectable benzene, toluene, or xylenes in the soil-gas samples, but showed the presence of other unidentified volatile organic compounds in soil gas north of the storage tank. The distribution of total concentrations of volatile organic compounds in the unsaturated zone indicated that a second plume about 200 feet long and 90 feet wide was present about 100 feet north of the storage tank. The second plume could have been the result of previous activities at this site during the 1950's or earlier. Activities at the site are believed to have included storage of solvents used at the nearby railyard and*

*flushing of tanks containing tar onto a gravel-covered parking area. The delineation of these plumes has shown that soil-gas analyses can be a useful technique for identifying areas of contamination with volatile organic compounds in shallow water-table aquifers and may have broad applications in similar situations where the water table is relatively close to the surface.*

## INTRODUCTION

The City of Jackson, West Tennessee, uses about 14 million gallons of ground water per day for domestic, commercial, and industrial uses. The water is obtained from relatively shallow wells drilled into the water-table sand aquifer within the Fort Pillow Formation (Parks and Carmichael, 1989).

In 1988, the U.S. Geological Survey, in cooperation with the Jackson Utility Division, began a comprehensive study of the hydrogeology of the general area near Jackson as a part of its ongoing water-resources investigation programs in Tennessee. The project was designed to provide the framework for the development of a ground-water flow model of the aquifer. As part of the investigation, the occurrence of contaminants in the unsaturated zone of the aquifer was investigated and the feasibility of using soil-gas analyses to identify areas where shallow ground water has been contaminated by volatile organic compounds (VOC) was tested.

In 1980, three underground fuel-storage tanks were installed at the South Water Treatment Plant for the Jackson Utility Division of the City of Jackson. In 1988, two of the three tanks failed testing for leaks and the tank containing unleaded fuel was found to be leaking at a coupling between the tank and the pump. The coupling was repaired, but the amount of fuel leaked was estimated at 3,000 gallons (Truman Murray, Jackson Utility Division, written commun., 1988). Part of the contaminated sand was removed from the area and replaced with clean sand. Some of the fuel-contaminated water was also removed from the excavation and the fuel fraction was decanted to drums and disposed. Volatile organic compounds also may have been introduced to the subsurface by previous activities at the site.

## **PURPOSE AND SCOPE**

This report documents the use of soil-gas analyses as an investigative technique in an area of known contamination as a first step toward monitoring fate and transport of VOC's in ground water. It also describes the applicability of the technique to other areas suspected of being contaminated by VOC's. This part of the investigation involved sampling soil gas at 97 locations in the unsaturated zone near the source of the contamination and analyzing the soil gas for VOC's. Field investigations were performed during December 5-14, 1988, and on March 13 and 14, 1989.

## **DESCRIPTION OF STUDY AREA**

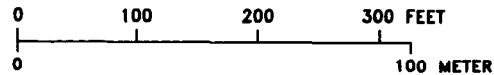
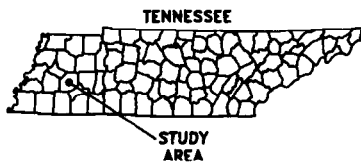
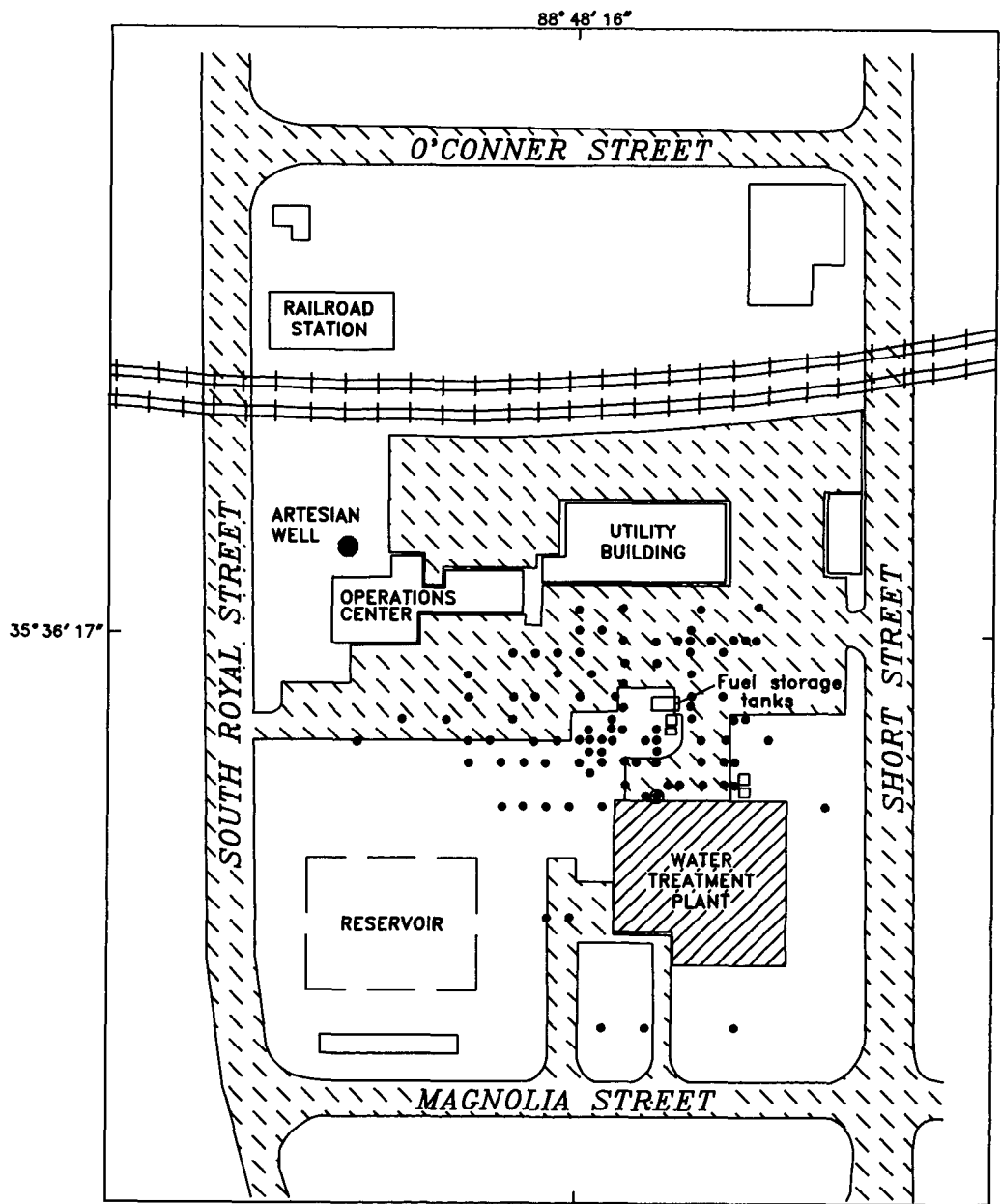
The study area is located at the site of a water-treatment plant in the southern part of the city of Jackson in Madison County, West Tennessee. The unsaturated zone at the project area consists predominantly of 2 to 6 feet of sand and clay. Ground water flows to the west and occurs at a depth of about 4 feet below land surface, but

in some topographically low areas, can be as shallow as 2 feet (Z.C. Bailey, U.S. Geological Survey, written commun., 1989). Much of the area near the underground fuel-storage tanks is paved with asphalt or contains office buildings (fig. 1). Prior to about 1980, the parking areas around the office buildings were gravel lots. Adjacent to the water-treatment plant is the former railroad station. Historically, the site of the water-treatment plant has served as a storage yard for freight near the rail line and as a city park and picnic area. Since 1950, the immediate area to the site has been used as a utility area for the storage of petroleum tars in above-ground tanks, storage of other paving materials, and for the servicing of vehicles and general maintenance of equipment.

## **SOIL-GAS SAMPLING AND ANALYSIS**

The unsaturated zone between the water table and the soil surface contains gases in pore spaces which are principally from the atmosphere and plant respiration (nitrogen, oxygen, carbon dioxide, argon, and others). When liquid petroleum products such as gasoline are spilled on the ground or buried as wastes, they may percolate through the porous media, sorbing onto particles until reaching the water table. In the saturated zone, the hydrocarbon fluids may dissolve in ground water, sink if more dense than water, or float on the water surface if less dense than water. If vapor pressures of the organic compounds or their degradation products are sufficiently high, and the amount of hydrocarbon present is significant, the volatile fractions may be present in the unsaturated zone gases in detectable quantities. Thus, it is possible to delineate the extent of these compounds in the soil and shallow ground water by analysis of organic compounds in the soil gas.

In this investigation, soil gases were sampled by making a hole about 1/2-inch diameter



**EXPLANATION**



PAVED AREA



BUILDING

- SOIL-GAS SAMPLE LOCATION POINT--  
Circled at point where ground water was sampled (⊙)

Figure 1.--Approximate location of sampling points for synthetic volatile organic compounds in soil gas at a site in the southern part of Jackson, Tennessee.

and about 3 feet deep using a slide hammer affixed to a steel drive point. Where it was necessary to sample soil gases below the paved areas, a hole was drilled through the 6-inch pavement using a percussion drill, then the hole was continued to depth using the drive point. Once the drive point was removed, a 5/16-inch diameter decontaminated copper probe about 40 inches long was inserted into the hole. Each probe was flattened to a chisel drive point with four perforations just behind the tip of the drive point. Decontamination of each probe was achieved by cleaning and rinsing with distilled water and oven baking overnight at 150 °C to remove volatile hydrocarbons. Ambient air was drawn through each probe and tested for traces of hydrocarbon prior to use. The probe was driven a few inches beyond the depth of the hole and then the soil was pressed around the top of the tubing to form a seal, preventing entrance of atmospheric gases down the annular space and into the probe. In paved areas, hydrocarbon-free modeling clay was pressed into the hole around the tubing to effect a seal. The probe was vacuum tested with a hand vacuum pump to ensure unimpeded withdrawal of soil gases. A portable vacuum pump was attached to the top of the probe with Tygon tubing and pumped for about 30 seconds before collecting a sample.

Semi-quantitative analyses for VOC were done using a Photovac 10S50 portable gas chromatograph equipped with a photoionization detector and electronic peak integrator. Separation of the organic compounds was achieved in 1/16-inch inside diameter columns packed with CSP-20M substrate. The system was equipped with a back flush column 6 inches long and an analytical column 4 feet long. This configuration permitted rapid analysis of the VOC. Compounds were tentatively identified in the field using retention times of pure standard compounds and comparing results from soil gases with the retention times of known compounds at the same temperature. Individual analyses were conducted at ambient air temperatures (columns

were not heated), which varied from 25 °C to 32 °C. Temperature increases of more than 2 °C required repeat runs of the standards. Syringes and soil probes were tested above ground by gas chromatography for VOC prior to insertion of the probe and withdrawal of the soil gases. Samples were withdrawn at the end of the pumping period by inserting the syringe needle into the Tygon tubing until the needle tip was actually inside the copper probe, thus limiting any potential contamination from the Tygon tubing. For further discussions of methodology, the reader is referred to Thompson and Marrin (1987).

Field determination of compounds was achieved by comparing retention times of VOC in soil gas with those of pure standard compounds, both run at the same temperature. Standards were prepared and used for interpretation of the soil-gas samples according to procedures recommended by the equipment manufacturer (Photovac, 1988, p. 66). Semi-quantitative standards containing benzene, toluene, meta-xylene, and ortho-xylene were prepared in clean 40 milliliter VOC bottles. Relative retention times and peak area were noted for each compound. Because of the complexity of obtaining quantitative results for such field procedures, calculations of concentration in parts per million of gas were normalized to the response of benzene. Resulting concentrations of total VOC in parts per million are thus based on benzene response in the photoionization detector.

## **EXTENT OF UNLEADED FUEL IN THE SUBSURFACE**

Gas chromatography with photoionization detection allows separation and analysis of individual volatile organic compounds such that a "fingerprint" of that group of compounds is produced (Spittler and others, 1985). Two fingerprints of VOC were observed in the chromatograms. One, representative of hydrocarbons



associated with unleaded fuel, was detected in samples collected near the fuel storage tanks, and a second set, representative of some other source of VOC, was detected in samples collected about 100 feet north of the fuel storage tanks.

### **DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS IN SOIL GAS FROM UNLEADED FUEL**

Chromatograms of a sample of unleaded fuel and of a benzene-toluene-xylene (BTX) standard showed the characteristic peaks of BTX (fig. 2a, 2b). The chromatogram of VOC of soil gases near the fuel tanks replicated those peaks, indicating the presence of benzene, toluene, and xylenes in the soil gas, and included other peaks, indicating the presence of lighter unidentified hydrocarbon fractions thought to be isomers of pentane and hexane, and perhaps some degradation products (fig. 2c). Semi-quantitative analyses using field gas chromatography showed concentrations of VOC in soil gas greater than 10,000 parts per million (ppm) near the source area (fig. 3). The contaminant plume was tracked to a concentration as low as 5 ppm. The plume was about 240 feet long, and 110 feet wide with the longest dimension extending westward along a boundary of the parking lot. Some parts of the plume extended south under a driveway to the water-treatment plant, and to the north under the main parking lot.

### **DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS IN SOIL GAS FROM UNKNOWN SOURCE**

Areal coverage of soil-gas sampling in the project area included the parking area north of the fuel tanks. Near the utility building to the north, soil gases were found to contain VOC, but

with negligible amounts of BTX, the principal components of the unleaded fuel (fig. 2d). The distribution of the VOC concentrations at this site showed a second area of elevated concentrations (greater than 1,000 ppm) occurred about 100 feet north of the fuel tanks (fig. 3). This area was about 200 feet long and 90 feet wide, with the long axis running east-west. Contouring the VOC concentrations over the area indicated the presence of two point sources of contaminants and two parallel plumes of VOC in the soil gas (fig. 3). Fuel residues were not found in soil gases in other areas sampled near the water-treatment plant.

### **PRESENCE OF VOLATILE ORGANIC COMPOUNDS IN WATER**

Considering the concentrations of VOC detected in soil gas near the fuel leak, a substantial amount of the fuel is presumed dissolved in water in the upper part of the water-table aquifer. Residual water, which collected in the excavation after removal of the fuel-soaked sand, reportedly contained free fuel product which was removed from the site, as previously noted. As further evidence for the presence of fuel in ground water, a shallow well (about 10 feet deep) adjacent to the leak, was qualitatively sampled for VOC analysis and showed the unleaded fuel fingerprint in the chromatogram. Additionally, water was encountered at a depth of 2 feet with one of the soil-gas probes inserted through the pavement near the water-treatment plant. A qualitative VOC analysis again showed the unleaded fuel fingerprint in the chromatogram.

### **APPLICATION OF TECHNIQUE TO OTHER AREAS**

Analyses of VOC in soil gas above shallow ground-water systems can be used to delineate

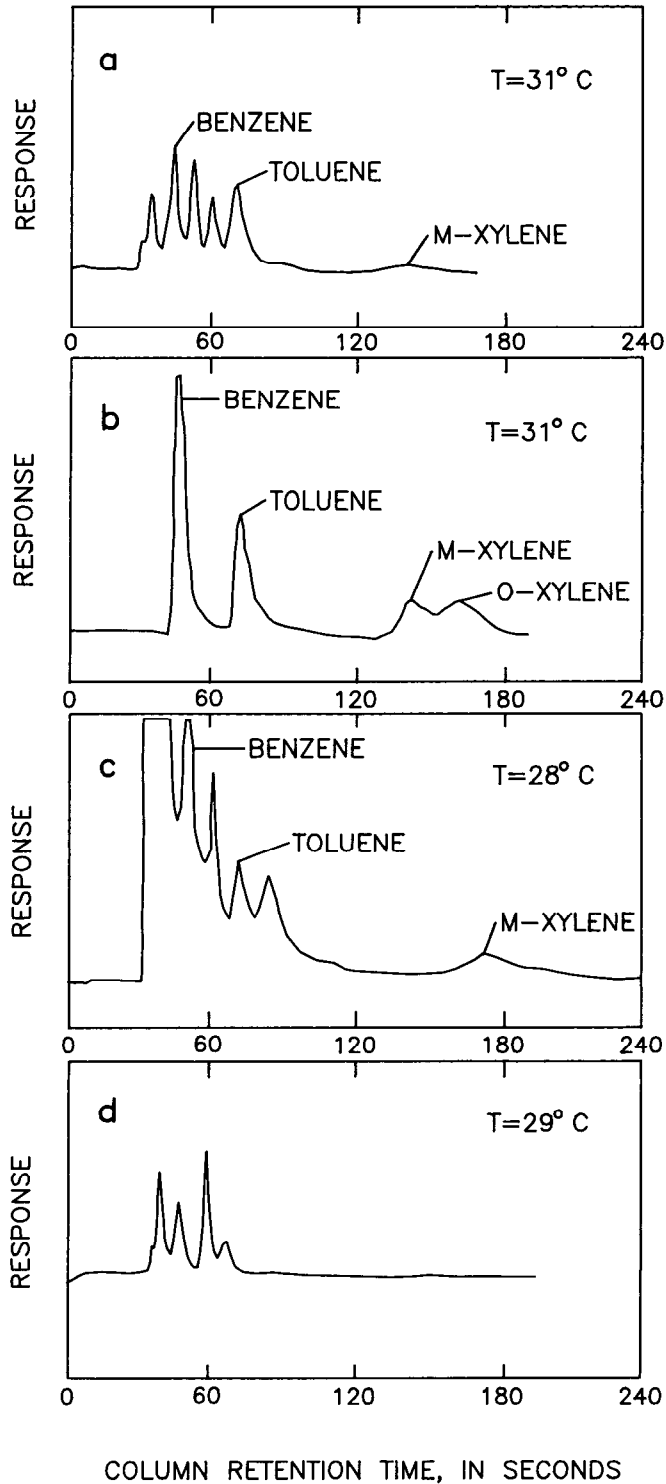
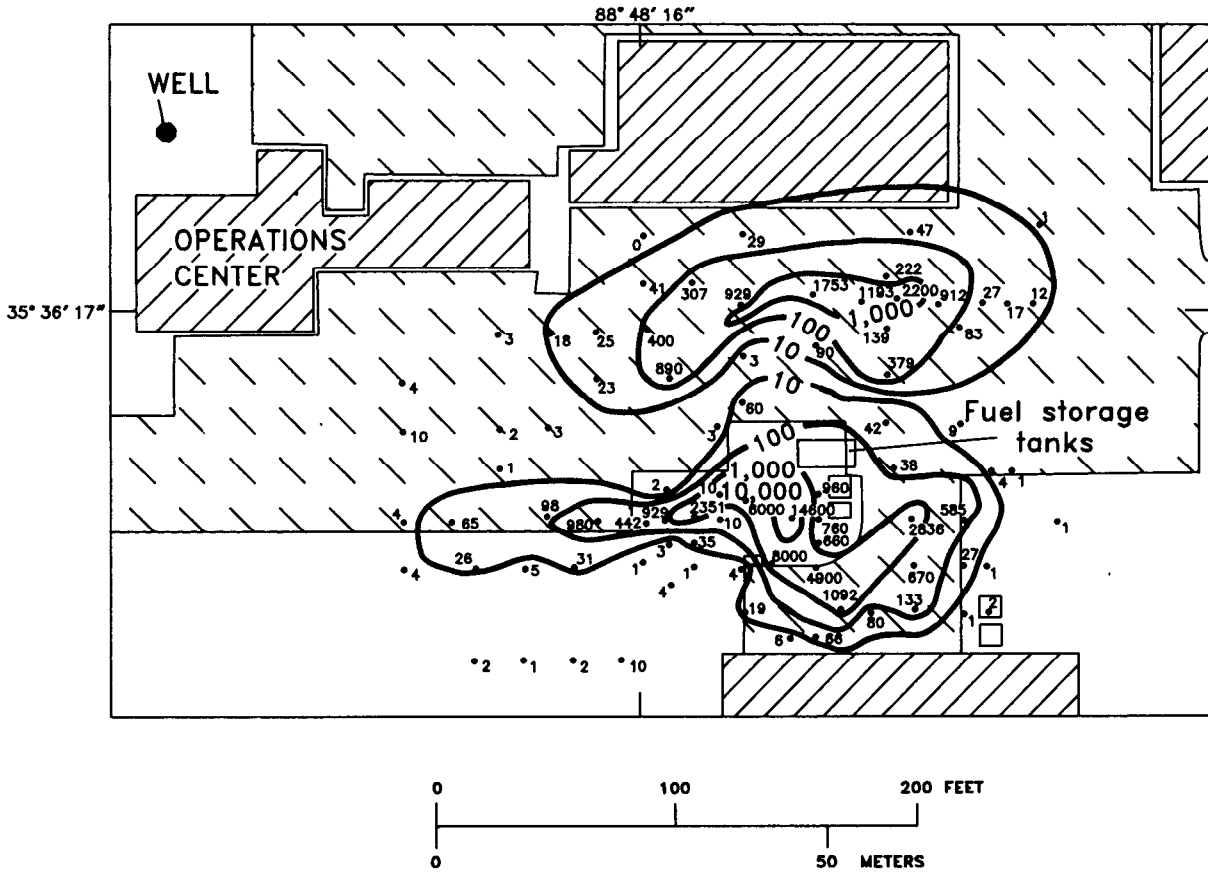


Figure 2.--Sample chromatograms of volatile organic compounds for: (a) unleaded fuel, (b) benzene-toluene-xylene standard, (c) soil gas above fuel leak, and (d) soil gas above unknown source.



**EXPLANATION**





-  PAVED AREA
-  BUILDING
-  — 10 — LINE OF EQUAL CONCENTRATION OF TOTAL VOLATILE ORGANIC COMPOUNDS—Value in parts per million. Interval is variable
-  • 2 SAMPLING SITE AND CONCENTRATION OF TOTAL VOLATILE ORGANIC COMPOUNDS—Value in parts per million

Figure 3.—Approximate location of sampling points and areal distribution of total volatile organic compounds in soil gas.

the extent of VOC in or floating on the water surface because BTX and other organic compounds associated with gasoline have a lower density than water, have relatively low solubility, and are highly volatile. Contributing to successful results at the Jackson site were the highly permeable matrix of the unsaturated zone and the shallow depth to the water table. This technique would be less effective in areas where strata in the unsaturated zone have low permeability and provide a relatively dense cap at some horizon over the saturated zone, and in areas where the water table is at substantially greater depths below land surface than at this site unless soil probes are inserted to depths near the water table. At Alamo, Tennessee, as part of a study in which this technique was tested in a somewhat different geologic environment, VOC's were not detected in the soil gas surrounding a well even though the well water contained a measurable quantity of VOC (Connor Haugh, U.S. Geological Survey, written commun., 1989). In the Alamo study, depth to water was 39 feet below land surface.

Where the technique can be applied, several advantages are offered. These include faster sampling techniques that are less expensive than drilling wells, and the ability to interpret and analyze the data on site. Knowledge of the relative magnitude of VOC concentration in a plume and the size, shape, and location of that plume as determined from soil-gas analysis also can be used to guide the design of well networks to monitor the fate and transport of hydrocarbons in the aquifer.

## CONCLUSIONS

Analyses of volatile organic compounds in soil gas above a shallow ground-water system in West Tennessee, where an underground fuel-storage tank leaked about 3,000 gallons of unleaded fuel to a water-table aquifer, has been shown to be an effective method for delineating contamination of the ground water by these compounds. Using this method, a plume of VOC about 240 feet long and 110 feet wide was identified at the site of the fuel tank. In the course of this study, a second plume of VOC in soil gas was found about 100 feet north of the fuel tank. This plume was about 200 feet long and 90 feet wide, and like the first plume, was oriented east-west. The VOC in soil gas from the second plume did not contain significant amounts of benzene, toluene, and xylenes that are characteristic of unleaded fuel. The source of VOC in the second plume is presently unknown. Previous activities in this area that may have contributed VOC are the storage and handling of solvents used at the nearby railyard and the flushing of tanks used to store petroleum tars prior to the time the parking lot was paved.

The technique probably would be successful in any area underlain by a sand-and-gravel aquifer where the depth to water is shallow. It may not be effective in areas where strata in the unsaturated zone have low permeability, and in areas where the water table occurs at substantially greater depths than at the Jackson site unless the soil gas probes are inserted deep enough to sample near the water table.

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