EVALUATION OF HIGH CONCENTRATIONS OF VOCs IN LANDFILL GAS: A CASE STUDY OF THE ROSE HILL REGIONAL LANDFILL SUPERFUND SITE

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ABSTRACT

Many municipal and industrial landfills generate landfill gas containing methane, carbon dioxide, and volatile organics. Field screening methods can successfully be used to delineate the extent of landfill gas migration and characterize the contaminants present in the landfill gas in a cost effective manner. At the Rose Hill Regional Landfill Superfund Site, landfill gas contamination and migration were studied at over 132 temporary points and 32 permanent points on and adjacent to three landfill areas. Samples were collected and analyzed for volatile organics using a field GC equipped with a photoionization detector (GC/PID). The gas was also analyzed for methane, carbon dioxide, and oxygen using various hand-held instruments. Methane and carbon dioxide concentrations ranged from 0 to 60% and total VOCs were as high as 76,000 mg/m^3 in the solid waste landfill, the primary area of concern. To confirm volatile organic field data, samples collected in SUMMA canisters were analyzed using laboratory method TO-14. On-site analysis of hydrogen sulfide and total mercaptans was also conducted. A qualitative comparison of field GC and SUMMA canister data indicated that the predominant volatile organic compounds were identified by the field GC. Quantitative comparisons of the field vs. laboratory method indicated a strong correlation between concentrations. To delineate the extent of off-site landfill gas migration, an additional 48 permanent and 26 temporary points were installed. Landfill gas was determined to be migrating from the solid waste area to the north, west and south with the highest concentrations of chlorinated VOCs in landfill gas to the north and west. The use of field methods allowed for accurate delineation of the landfill gas plume with a considerable savings of time and resources.

INTRODUCTION

Site Description. The Rose Hill Superfund site is located within the town of South Kingstown, Rhode Island in the village of Peace Dale (See Figure 1). The site lies about five miles west of Narragansett Bay and two miles north of Wakefield, RI. The site is bordered by Rose Hill Road to the west, Saugatucket River to the east, and residential private property to the north and south. The seventy acre site is located in an abandoned sand and gravel quarry, which is owned in part by the town and in part the estate of a private individual. The site consists of three separate inactive disposal areas, including a solid waste, a bulky waste, and a sewage sludge area. An active transfer station is located on the site, south of the disposal areas.

Site History. The Rose Hill Regional Landfill began operation in 1967, accepting domestic and industrial wastes from the residents of South Kingstown and Narragansett. The solid waste disposal area was active from 1967 to 1982 and the other two landfills were active from the late 1970s to 1983. Upon reaching state-permitted maximum capacity, operations ceased and the landfill was closed. A municipal transfer station was established at the site in 1983, and continues operation. During the years of landfill operation, repeated disposal of an industrial laminating adhesive was documented. The town of South Kingstown began installing monitoring wells onsite and monitoring nearby private wells in

1978. The Rhode Island Department of Environment Management (RIDEM) analyzed samples of adhesive waste in 1979 and found they contained VOCs. In 1984, the town of South Kingstown conducted site inspections that showed the presence of VOCs in on-site groundwater and soils, and in nearby residential wells. The site was added to the National Priorities List in 1989. After negotiations with the Potentially Responsible Parties (PRPs) in 1990, EPA obligated Superfund money to conduct the Remedial Investigation/Feasibility Study (RI/FS) as a fund lead. The final RI report was completed in May 1994.

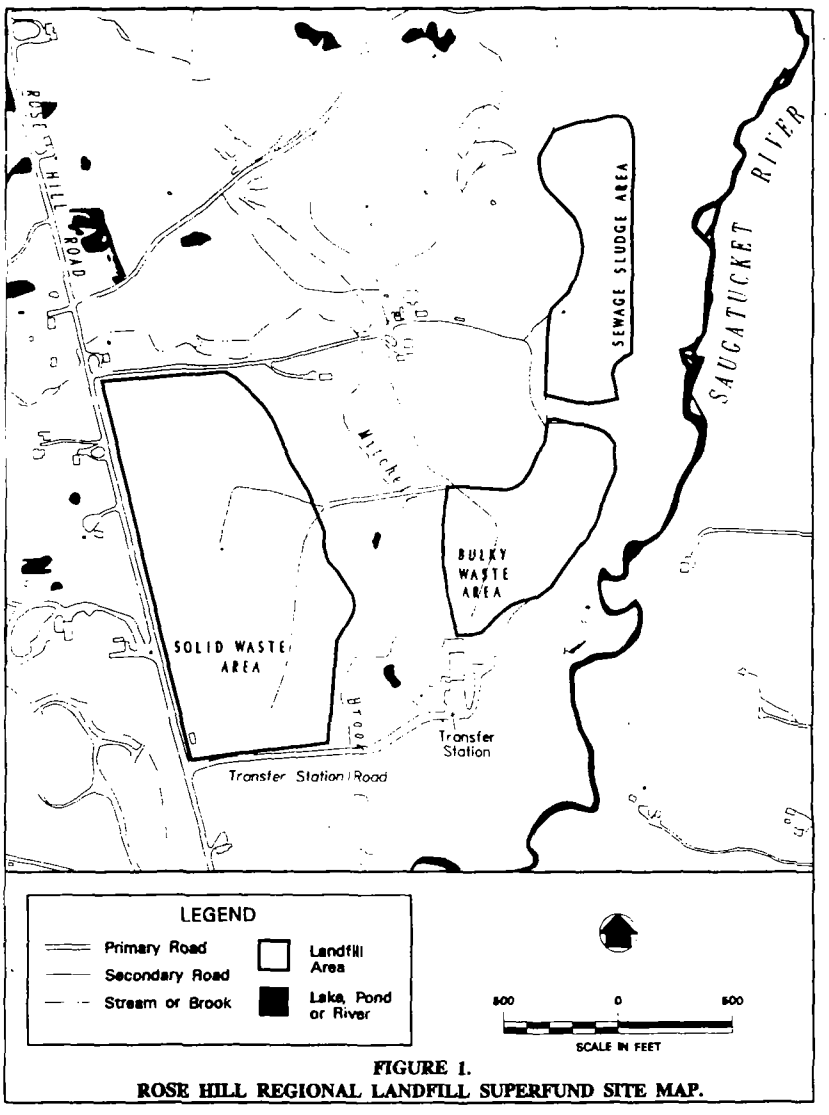

FIGURE 1.
ROSE HILL REGIONAL LANDFILL SUPERFUND SITE MAP.

METHODS

Sampling Location. During the initial phase of the landfill gas study conducted in June and July of 1991, 164 points on the three landfill areas and around the perimeter of the solid waste area were sampled to determine the presence of contaminants in landfill gas, the source areas, and whether off-site migration was occurring. Results of the landfill gas studies conducted on the solid waste area, its perimeter, and off-site migration are the focus of this paper. Eighty-five temporary points in the solid waste area, shown in Figure 2, were located on a 100-foot-by-100-foot grid. Once a pattern of contamination was established, some grid points were not analyzed. A sampling depth of 2.5 to 3 feet was measured throughout the solid waste area. Thirty-two permanent landfill gas monitoring points were installed and sampled around the perimeter of the solid waste area at approximately 100-foot intervals at a depth of 3 feet to monitor the potential of off-site migration.

Each location was analyzed for percent levels of methane (CH_4) and carbon dioxide (CO_2) using an infrared gas analyzer (ADC model LFG 10). Low levels of methane (less than 1,000 ppm) were measured using an flame ionization detector (FID; Foxboro OVA 128). Oxygen (O_2) and the lower explosive limit (LEL) were measured using a combustible gas indicator (CGI; Industrial Scientific MX241). Each point was analyzed for volatile organics with a portable field gas chromatograph (GC).

Sampling Procedure. Temporary sampling points were installed using a K-V Hefty® soil gas sampling system to drive a 3/4-inch-OD hollow steel rod into the ground. A slotted section at the bottom allowed

landfill gas to pass into the hollow steel rods from which samples were drawn for analysis. The sampling apparatus is illustrated in Figure 3. The landfill gas was initially purged at a flow rate of 1 liter per minute and the vacuum required was recorded. Approximately 1 liter of landfill gas was drawn through the sampling system and the 125-mL sampling bulb, before it was detached and stored for analysis using the field GC. Typically the time from sampling until analysis was 15 to 30 minutes. After collection of the bulb sample, measurements were made using hand-held measurements for $\%CH_4$, $\%CO_2$, $\%O_2$ and %LEL. In some instances, VOCs were also measured using a PID. Not all of these measurements were possible at every point due to weather conditions and time constraints.

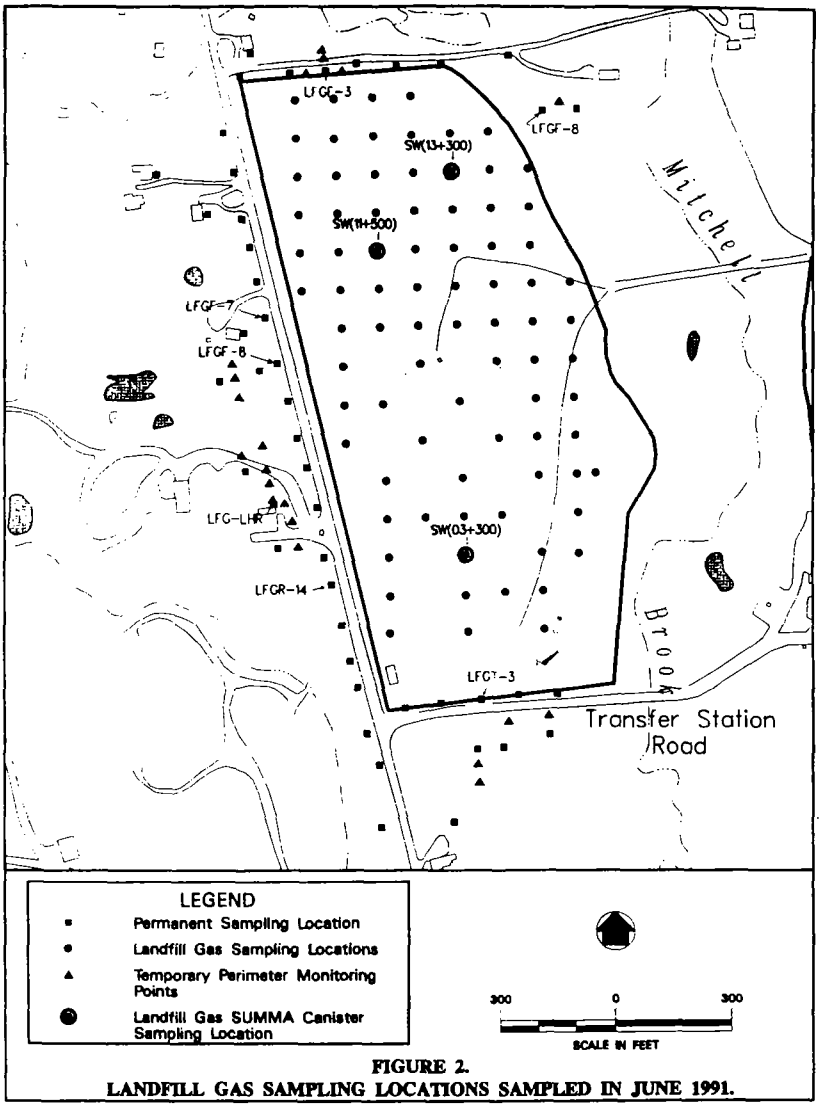

FIGURE 2.
LANDFILL GAS SAMPLING LOCATIONS SAMPLED IN JUNE 1991.

Permanent sampling points were installed around the perimeter of the solid waste area with K-V Hefty soil gas sampling equipment, using a method adapted from Kerfoot and Soderberg (1989). The procedure was 1) drill a pilot hole to a depth of approximately 3 feet using the K-V Hefty system, 2) insert a slotted aluminum shield point threaded onto 1/4-inch tubing to the bottom of the hole, 3) pour glass beads or sand into the hole around the shield point. 4) pour crushed bentonite pellets on top, 5) hydrate the bentonite to ensure a gas-tight seal with the tubing, and 6) place a protective PVC casing and locking cap above ground to protect the point. Figure 4 is a diagram of a completed permanent landfill gas monitoring point. Sampling was performed in the same manner as the temporary landfill monitoring points.

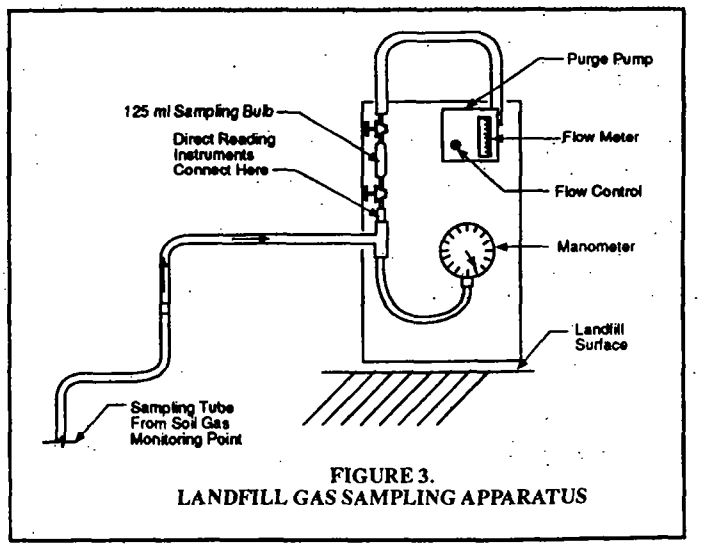

FIGURE 3.
LANDFILL GAS SAMPLING APPARATUS

Gas Chromatographic Data Interpretation. To qualitatively identify individual volatile organics, an HNu 311 portable field GC equipped with an 11.7 eV photoionization detector (PID) lamp, 25 meters capillary column, and a 0.5-meter precolumn

was used. Tentative identification of volatile organics was made by comparing retention times of chromatographic peaks in sample runs with those in standard runs.

Thirteen target compounds routinely used for standardization of the field GC were: methylene chloride, *trans*-1,2-dichloroethene *(trans-1,2-DCE)*, 1,1-dichloroethane (1,1-DCA), *cis*-1,2-dichloroethene *(cis-1,2-DCE)*, chloroform, 1,1,1-trichloroethane (1,1,1-TCA), benzene, trichloroethene (TCE), toluene, tetrachloroethene (PCE), ethylbenzene, *m*-xylene, and *o*-xylene.

Concentrated gas standards were prepared from neat (pure solvent) compounds by injecting a known volume into a glass sampling bulb. Secondary dilution was used to prepare fresh working standards daily. For analysis, samples and standards were taken from the glass sampling bulb using a syringe injected directly onto the head of the precolumn.

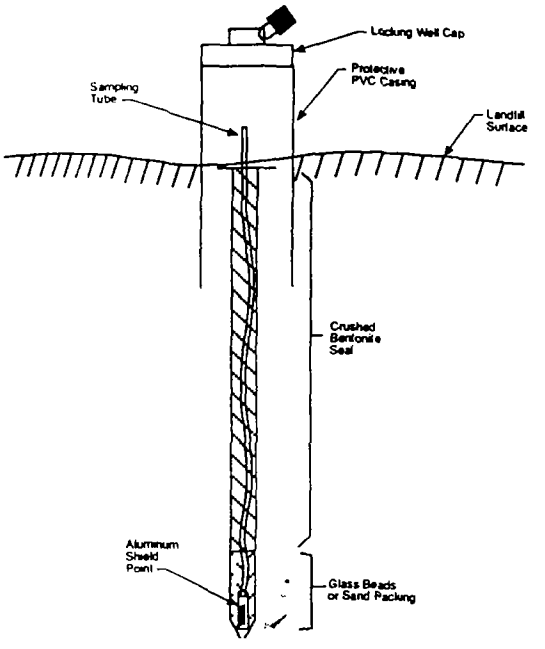

FIGURE 4.
PERMANENT LANDFILL GAS SAMPLING POINT

Delineation of Off-Site Landfill Gas Plume. Based on sampling conducted in June, July and September 1991, four areas of concern were defined: 1) north of the solid waste area near LFGF-3; 2) northeast of the solid waste area near LFGF-8; 3) west of Rose Hill Road, between LFGR-7 and LFGR-14; 4) south of the solid waste area and the Transfer Station Road.

In December 1991, additional off-site landfill gas monitoring was conducted to further delineate the migration of landfill gas from the site study area. Twenty-six temporary points were analyzed at various depths and the field GC was used to analyze 25 to 33% of the samples. Sixteen additional permanent points were installed in response to the migration of landfill gas near several residences. Eight points were installed adjacent to houses along Rose Hill Road and eight locations were installed at points determined during the delineation of an off-site landfill gas plume. The same instrumentation used during the initial investigation was used during this phase. Each of the areas of concern and the points sampled to delineate the off-site plume are indicated on Figure 2. Many points were sampled at more than one depth to determine if the landfill gas may be migrating preferentially at deeper depths.

Since the extent of landfill gas migration was expected to be greatest during the winter and early spring due to snow cover and the presence of a frost layer, monthly sampling of the permanent sampling points was conducted in December 1991 and January, February, March, and April of 1992. For the first three months, 24 selected points were sampled based on the previous history of contamination, field conditions, and the proximity to residential buildings. The field GC was used to analyze 25 to 33% of the monthly monitoring samples. In April 1992, all 48 permanent points were sampled as field conditions permitted and all of the April samples were analyzed by field GC.

Modifications to Field GC Methodology. Modifications to the field GC methodology were made in February 1992 to include the use of a 10.2-eV-PID lamp. Due to the deterioration of the 11.7-eV lamp that was in use, a 10.2-eV lamp was used to confirm the results from the 11.7-eV lamp. Another

modification in April 1992 included the addition of vinyl chloride to the field GC target compound list. Vinyl chloride became a concern when early eluting compounds were detected with the 10.2-eV lamp. The approximate quantitation limit for vinyl chloride was 40 mg/m^3.

The 10.2-eV lamp is unable to detect the four saturated compounds (methylene chloride, 1,1-DCA, chloroform, and 1,1,1-TCA), since their ionization potentials are 11.0-eV and above. Although the 11.7-eV lamp is able to detect the four saturated compounds, it is less durable than the 10.2-eV lamp and exhibited considerable loss of sensitivity over time. The 10.2-eV lamp was used in April 1992, because it is much more sensitive to vinyl chloride than the 11.7-eV lamp. This is important since the detection of vinyl chloride was of particular concern in nearby homes.

Laboratory Analysis. To verify field GC results, three landfill gas samples from the solid waste areas were collected in May 1992, for quantitative laboratory analysis, as shown in Figure 2. Sampling locations were selected based on the elevated volatile organic concentrations measured during the site reconnaissance, spacial distribution and variations in landfill gas composition. A Geoprobe® System was used for the collection of all these landfill gas samples for laboratory analyses. Collection of samples for field screening and analysis using hand-held instruments followed the procedure previously described. Samples were submitted to a Contract Laboratory Program (CLP) laboratory for volatile organic analysis by Method TO-14 modified for high-concentration samples. The landfill gas samples were collected in SUMMA canisters as described below. Total-reduced-sulfur compounds were analyzed in an on-site laboratory using ASTM Method D-2385-81.

Initially a depth profile was conducted using hand-held instruments and the field GC to screen depths at 3-foot intervals to a maximum of 12 feet. The depth with the highest volatile organic concentration was used for the collection of samples for laboratory analysis of volatiles and field analysis of reduced sulfur. A diagram of the sampling equipment is shown in Figure 5. All fittings and tubing that contacted the sample were either Teflon® or steel. A small pump purged the tubing leading to the SUMMA canister prior to sampling. After closing the valve leading to the purge pump, the SUMMA canister was filled by opening the valve on the SUMMA canister. The laboratory provided precalibrated mass-flow controllers set to a flow rate of approximately 200 cc/min. A flow time of approximately 20 minutes was used to allow about 4 liters of sample to enter each canister. Precise flow rates and sampling times were measured in the field. An impinger technique based on ASTM Method D-2385-81 was used to sample for hydrogen sulfide and total mercaptans. A diagram of this sampling apparatus is shown in Figure 6. Each location sampled for volatile organics using Method TO-14 was also sampled for reduced sulfur.

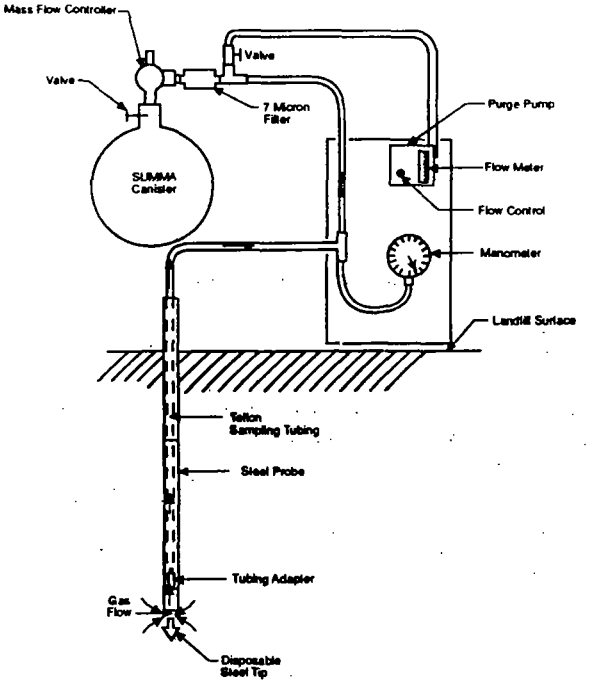

FIGURE 5. SOIL GAS SAMPLING SYSTEM FOR SUMMA CANNISTER SAMPLING

To ensure the validity of the data collected, strict quality control measures were maintained by careful and thorough decontamination of the sampling system, the analysis of blanks, performance evaluation samples, and field duplicates.

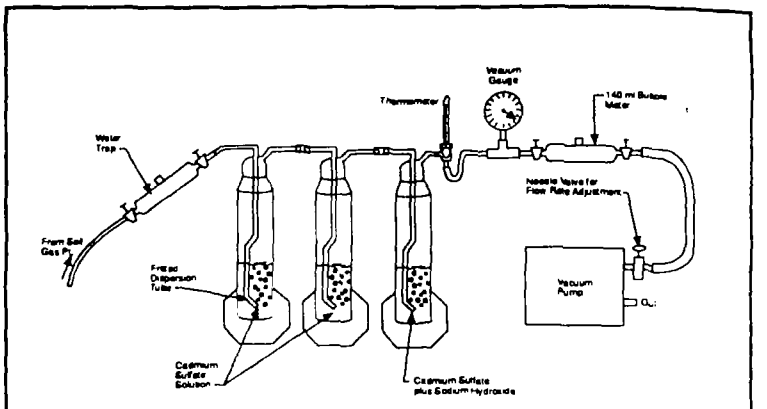

FIGURE 6. REDUCED SULFUR SAMPLING SYSTEM

RESULTS

Solid Waste Area. Carbon dioxide and methane concentrations were greater than 35% throughout most of the solid waste area and ranged as high as 62% for carbon dioxide and 60% for methane. Figure 7 depicts concentration contours for methane in the solid waste area. Oxygen concentrations were generally depressed from ambient air concentration to as low as 1%. Volatile organics were present throughout the disposal area but appear to have been most elevated at SW(11+500) and SW(13+200). Figure 8 shows total VOC concentration contours as measured by field GC over the solid waste area. The relative concentrations of volatile organic compounds in the landfill gas also varied. Data from selected landfill gas sampling points are shown in Table 1. The primary VOCs detected in the northern part of the landfill were chlorinated organic compounds. In the southern part of the landfill aromatic, BTEX, compounds were more prevalent. This was confirmed by the SUMMA canister analysis. Freon compounds, ketones, carbon disulfide, and bromoform were also found sporadically in SUMMA samples. Reduced sulfur analysis indicated hydrogen sulfide results ranging from 1.0 to 6.3 mg/m^3. No mercaptan sulfur was detected.

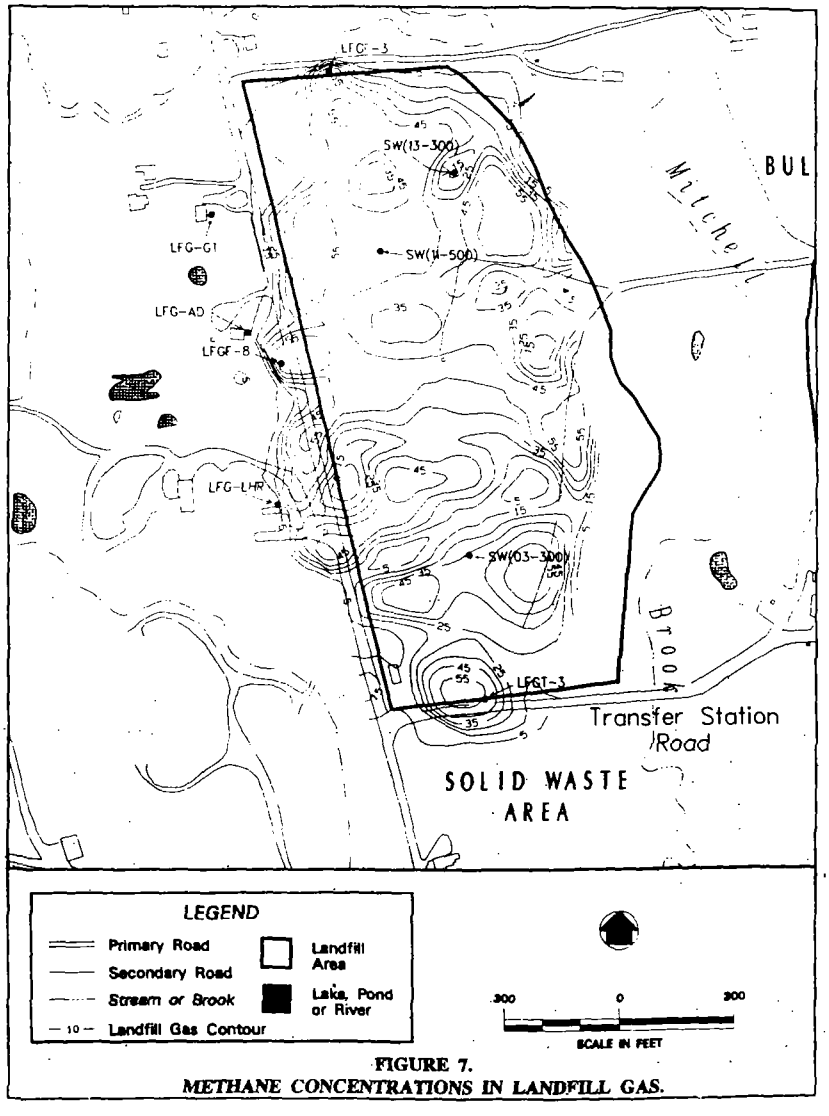

FIGURE 7.
METHANE CONCENTRATIONS IN LANDFILL GAS.

Perimeter. Three primary areas of landfill gas migration were indicated from the July 1991 sampling data. These areas were characterized by elevated carbon dioxide, methane, and volatile organic measurements and by reduced oxygen content. Figures 7 and 8 indicate three primary areas of landfill gas migration: to the north, west and south. Table 2 presents selected data from the April 1992 sampling round. The data points presented are the highest points of contamination migration.

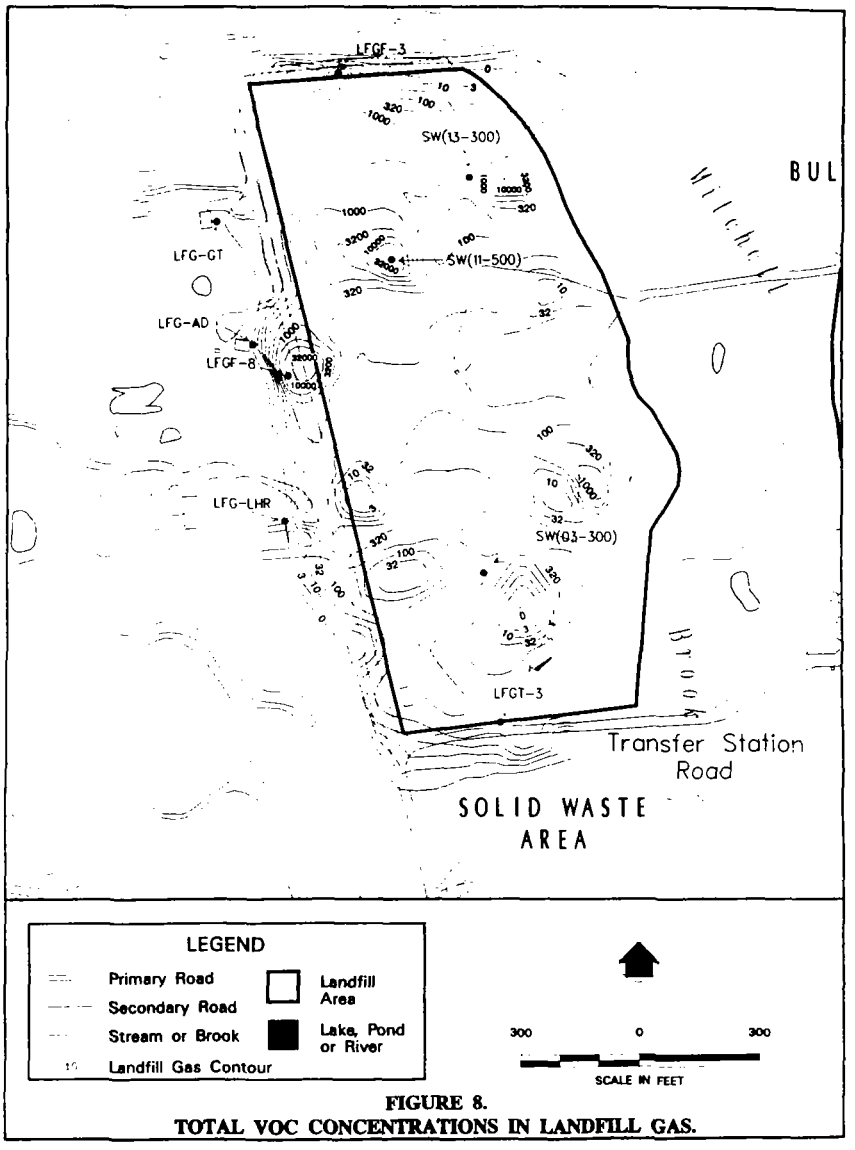

FIGURE 8.
TOTAL VOC CONCENTRATIONS IN LANDFILL GAS.

At LFGF-08, located northeast of the landfill, 4.3 mg/m^3 of TCE was identified in July 1991 and its presence was confirmed in later sampling rounds. Other typical components of landfill gas such as methane, carbon dioxide, or other volatile organics were not detected at LFGF-08. Thus, although TCE was a common component of landfill gas in the solid waste area, its presence at LFGF-08 did not appear to be due to landfill gas migration.

The volatile compounds identified at the southern end of the landfill were different from those identified to the north and west of the landfill. For example, *cis*-1,2-DCE, a major component at LFGR-08 and LFGF-03, was not present at any of the points along the transfer station road.

The largest area of off-site migration was along the western perimeter of the landfill. Methane, carbon dioxide, and some volatiles appeared to have migrated 200 feet from the perimeter of the solid waste disposal area near LFG-LHR. The nature of the volatile constituents varied as the landfill gas plume migrated from the solid waste area. Compounds that are less volatile (ethylbenzene and xylenes for example) were not detected in the landfill gas collected at points farthest away from the landfill. Other more volatile compounds were detected at these points using the field GC. Although these compounds were not specifically identified, since they were not part of the standard mixtures routinely used, the field GC did provide information concerning their volatility.

At five of the eight residential monitoring points, no volatile organics or methane were detected during any of the landfill gas monitoring rounds. At three of the residential monitoring points (LFG-AD, LFG-GT and LFG-LHR), volatile organics were detected using the field GC. At LFG-LHR, as much as 1.6% methane was also detected. Volatile organics were first detected at LFG-LHR, LFG-GT, and

SAMPLE ID:		SW(13+300)			SW(11+500)			SWD(13+300)			SW(03+300)		
	SUMMA	SUMMA DATA		FIELD GC	SUMMA DATA		FIELD GC	SUMMA DATA		FIELD GC	SUMMA DATA		FIELD GC
COMPOUND	CRQL	ppbv	mg/m3	mg/m3	ppbv	mg/m3	mg/m3	ppbv	mg/m3	mg/m3	ppbv	mg/m3	mg/m3
TARGET COMPOUNDS(1)													
Dichlorodifluromethane	5	12000	59	NA	9200	45	NA	22000	100	NA	210	1.0	NA
Freon 114	5	--	--	NA	280	2.0	NA	--	--	NA	--	--	NA
Chloromethane	5	--	--	NA	1400	2.9	NA	--	--	NA	--	--	NA
Vinyl Chloride	5	490000	1300	85	400000	1000	83	1200000	3100	NA	1200	3.1	--
Chloroethane	5	6600	17	NA	--	--	NA	--	--	NA	450	1.2	NA
Trichlorofluoromethane	5	--	--	NA	250	1.4	NA	--	--	NA	32	0.18	NA
1,1-Dichloroethene	5	5600	22	NA	3800	15	NA	8100	32	NA	10	0.040	NA
Carbon Disulfide	5	--	--	NA	280	0.9	NA	--	--	NA	38	0.12	NA
Freon 113	5	--	--	NA	31	0.24	NA	--	--	NA	--	--	NA
Methylene Chloride	5	8000	30	--	2400	8.3	162	19000	66	NA	200	0.69	--
trans-1,2-Dichloroethene	5	3600	14	TRACE	1000	4.0	142	6700	27	NA	22	0.087	--
1,1-Dichloroethane	5	22000	89	--	3900	16	--	34000	140	NA	53	0.21	--
cis-1,2-Dichloroethene	5	2300000	9100	12204	1800000	7100	3824	5900000	23000	NA	380	1.5	7
1,1,1-Trichloroethane	5	1900	10	--	230	1.3	--	--	--	NA	--	--	--
Carbon Tetrachloride	5	--	--	NA	45	0.28	NA	--	--	NA	--	--	NA
Benzene	5	2500	8	--	620	2.0	--	--	--	NA	820	2.6	TRACE
Trichloroethene	5	2700	14	--	5700	31	196	--	--	NA	84	0.45	12
4-Methyl-2-pentanone	5	1600	6.5	NA	--	--	NA	--	--	NA	--	--	NA
Toluene	5	22000	83	109	19000	71	141	62000	230	NA	5500	21	38
Tetrachloroethene	5	--	--	--	1200	8.1	--	--	--	NA	84	0.6	NA
Ethylbenzene	5	--	--	--	3000	10	18	--	--	NA	5800	25	42
m,p-Xylene	5	--	--	NA	5600	24	NA	--	--	NA	9400	41	NA
o-Xylene	5	--	--	--	1000	4.3	--	--	--	NA	2500	11	--
Bromoform	5	--	--	NA	230	2.4	NA	--	--	NA	--	--	NA
1,3,5-Trimethylbenzene	5	870	4.3	NA	150	0.74	NA	--	--	NA	210	1.0	NA
1,2,4-Trimethylbenzene	5	--	--	NA	220	1.1	NA	--	--	NA	500	2.5	NA
1,4-Dichlorobenzene	5	--	--	NA	--	--	NA	--	--	NA	72	0.43	NA
Benzyl Chloride	5	--	--	NA	--	--	NA	--	--	NA	--	--	NA
Total VOCs		2879370	10758	29882	2259536	8352.	10844	7251800	26694	NA	27565	113.0	576
REDUCED SULFUR(2) (mg/m3)			6.28			1.04			NA			5.79	
HAND HELD INTRUMENTS													
Carbon Dioxide (% by volume)			38			23			NA			30	
Methane (% by volume)			59			22			NA			44	
Oxygen (% by volume)			0.7			6.8			NA			0.6	
PID(ppm using 10.6 eV lamp)			35			48			NA			0	
SUMMA DILUTION FACTOR:			7888			358			28220			32	
DATE SAMPLED:			05/12/92			05/12/92			05/12/92			05/13/92	
DEPTH OF SAMPLE (feet):			12			5			12			6	
REMARKS:								Collected 6 hrs after SW(13+300)					

Footnotes:
-- Indicates that an analyte was not detected in the sample by the method indicated.
NA - Indicates that data is not available for the analyte indicated.
(1) - The compound list presented is for detected compounds only. Other compounds were analyzed for but not detected.
(2) - The reduced sulfur results are for hydrogen sulfide. Mercaptan compounds were also tested for but not detected.

TABLE 1. COMPARISON OF SUMMA AND FIELD GC DATA COLLECTED ON THE SOLID WASTE AREA

PARAMETER	LFGF-03	LFGF-08	LFGR-08	LFGT-03	LFG-AD	LFG-GT	LFG-LHR
FIELD GC							
Vinyl Chloride	3533	--	3749	--	--	--	--
t-1,2-DCE	--	--	--	--	--	--	--
c-1,2-DCE	1004	--	5034	--	--	--	--
Benzene	--	--	--	TRACE	--	--	--
TCE	30	4	--	1	--	--	--
Toluene	89	--	241	21	--	--	--
PCE	NA	--	--	NA	--	--	--
Ethylbenzene	TRACE	--	--	23	--	--	--
m-Xylene	--	--	--	15	--	--	--
o-Xylene	--	--	--	--	--	--	--
Total VOC (1)	30546	7	66945	322	34	4	18
HAND HELD INSTRUMENTS							
Carbon Dioxide	28.3	0.57	41	40.2	9.3	1.83	17.9
Methane	31.4	0	57.4	54.3	0	0	1.6
PID(10.6)	18.3	16.5	22.2	0	0	0	0
PID(11.7)	716	100	NA	115	31.9	0	180.5
LEL	NA	0	NA	NA	7	7	NA
Oxygen	0.1	20.6	0.1	1	11.1	19.7	0.7

FOOTNOTES:
-- - The result was non-detected for the indicated parameter.
NA - Due to matrix interferences or instrument failure a result is not available for the listed parameter.
(1) - Total VOCs by field GC include both target compounds and an estimation of non-target compound concentrations.

TABLE 2. SELECTED PERIMETER MONITORING POINT DATA FROM APRIL 1992

LFG-AD during the February sampling. This was also the first time a 10.2-eV lamp was used in the field GC. A discussion of the use of a 10.2- vs. 11.7-eV lamp was described previously. Total volatile organic and methane concentrations at these three points are summarized in Table 2. Carbon dioxide was also detected at LFG-LHR and LFG-AD. While generally not considered hazardous, carbon dioxide as a landfill gas constituent may indicate the leading edge of a landfill gas plume.

Comparison of Field GC Data and Method TO-14 SUMMA Canister Data. Compounds detected by the field GC analysis were identified by retention time only on a single chromatographic column. Thus, the compound identities were considered tentative. Laboratory Method TO-14 analysis utilizes both gas chromatography and mass-spectra (GC/MS). Therefore, there is more certainty in the identity of the target compounds detected at concentrations above the quantitation limits. GC/MS data are far less affected by matrix interferences than GC data from nonspecific detectors such as the PID. With the GC/MS data, ions arising from target compounds can be selectively searched and interfering nontarget ions ignored unlike the GC/PID data. Table 7 presents both detected SUMMA canister results and field GC results for each of the samples confirmed by laboratory analysis. However, both a qualitative and quantitative comparison between the two methods proved favorable as described below, further emphasizing that field methods are a useful, cost effective, and efficient way to obtain accurate data.

Qualitative Comparison. Of the 14 compounds detected in the initial SUMMA canister collected at SW(13+300), nine were field GC target compounds. Four of the nine field GC target compounds were below the field GC quantitation limits and therefore were not evaluated. Three compounds, vinyl chloride, *cis*-1,2 DCE, and toluene, were detected by both methods. Two compounds, 1,1-DCA and TCE, were detected by SUMMA canister analysis but were not detected by the field GC because the large chromographic peak for *cis*-1,2-DCE obscured the relatively low-concentration, closely eluting peaks for 1,1 DCA and TCE.

At SW(11+500), 24 method TO-14 SUMMA canister target compounds were detected including all of the 14 field GC target compounds. Only one compound, 1,1,1-TCA, was detected below the field GC quantitation limit. Eight compounds were detected and quantitated using both methods: vinyl chloride, methylene chloride, *trans*-1,2-DCE, *cis*-1,2-DCE, TCE, toluene, ethylbenzene and *m,p*-xylene. Five compounds were reported from SUMMA canister analysis above the field GC quantitation limits but were not reported in the field GC data. As with sample SW(13+300) the large *cis*-1,2-DCE peak in SW(11+500) obscured the smaller closely eluting peaks for 1,1-DCA, chloroform, 1,1,1-TCA, and benzene. The compound *o*-xylene was obscured by late-eluting, nontarget interfering peaks.

The third point analyzed by both methods was SW(03+300). Of the 20 SUMMA canister target compounds detected, 12 were field GC target compounds. Five of these 12 compounds were below the field GC quantitation limits and could not be evaluated. Six compounds were quantitated by both methods: *cis*-1,2 DCE, benzene, TCE, toluene, ethylbenzene, and *m,p*-xylene. The compound *o*-xylene was obscured by late-eluting, nontarget interfering peaks.

Thus, comparison of the field GC chromatograms and the SUMMA canister chromatograms at each sampling point confirmed that the largest peaks in the field chromatograms have been identified. The relative sizes of these large peaks also appeared to be proportional to the remaining peaks in the chromatograms from each of the two methods.

Quantitative Comparison. A simple statistical comparison of the field GC and laboratory data requires that an analyte be detected by both the field GC and the laboratory analysis. Of samples analyzed in all three landfill areas by both field GC and TO-14, only 24 results were detected in both samples. The remaining results were not detected by either the field GC, the laboratory analysis or both. The correlation coefficient for the least-squares-linear regression is 0.927, which demonstrates fairly good agreement between the two data sets. However this analysis is dominated by four very large results (>1000 mg/m^3). If these results are excluded then the correlation drops to 0.633. Four of these results were for vinyl chloride which is particularly difficult to analyze by field GC. The field GC data for vinyl chloride were approximately an order of magnitude lower than the SUMMA canister data. Field GC versus laboratory comparisons for *cis*-1,2-DCE and toluene, (the two compounds most frequently detected) are 0.944 and 0.914, respectively, demonstrating strong agreement between the field and laboratory results.

SUMMARY AND CONCLUSIONS

At the Rose Hill Regional Landfill, landfill gas generated in the disposal areas was characterized by elevated methane, carbon dioxide, and volatile organic concentrations. Hydrogen sulfide was also found. In the solid waste area, numerous volatile organics were found in landfill gas; however, vinyl chloride, *cis*-1,2-DCE, and toluene were the major components. These compounds were also the major volatile organics in landfill gas north and west of the solid waste area. West of the Rose Hill Road, volatile organics were detected on three residential properties. Thus, off-site migration of landfill gas was evident.

Field-screening techniques can successfully be used to characterize the contaminants present in landfill gas and delineate the extent of landfill gas migration in municipal and industrial landfills. The use of hand-held instruments and a field GC to measure methane, carbon dioxide and volatile organics proved an accurate, cost-effective, and efficient approach to the evaluation of landfill gas contamination and migration at the Rose Hill Regional Landfill. Qualitative and quantitative comparisons of field GC to laboratory data for volatile organics demonstrated strong agreements with the two methods.

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