

AIR EMISSIONS AT A MUNICIPAL SOLID WASTE LANDFILL

Joyce E. Capenter
Environmental Risk Limited
Bloomfield, Connecticut

Jeremy N. Bidwell
Environmental Risk Limited
Bloomfield, Connecticut

ABSTRACT

The on-site and off-site ambient air concentrations of non-methane organic compounds (NMOC) and hydrogen sulfide were evaluated at a regional municipal solid waste (MSW) landfill. A target list was developed to reflect those compounds typically found at MSW landfills that have potential health effects or odors. The on-site effects on ambient air were estimated conservatively by collecting air samples 10 to 13 cm above the landfill surface. The off-site impacts were predicted using air dispersion modeling that considered both fugitive and point source emissions and were based on landfill gas sampled from an active well collection system. The on-site and off-site ambient air concentrations were compared to levels set by regulatory requirements (Connecticut's Hazard Limiting Values or HLVs) and odor threshold levels. No compound exceeded the HLVs either on- or off-site. No compounds detected on-site exceeded their odor thresholds. Several compounds evaluated at one-half their detection limit did exceed the odor threshold on-site. Only hydrogen sulfide exceeded its odor threshold off-site but remained below Connecticut's Odor Limit Value.

BACKGROUND

The municipal solid waste landfill described in this study is approximately 280,000 m² located in an urban Connecticut setting and has been in continuous use for over fifty years. The landfill accepted unprocessed municipal solid waste until the late 1980's. Since then, the landfill has accepted only bulky waste, ash residue, and process residue resulting from the processing and burning of MSW. At the time of testing, the majority of

landfill side slopes were under final cover. Intermediate cover was being placed on approximately 81,000 m². The working faces received daily cover. An active gas extraction system and enclosed flare have been in use for two years. The landfill operator commissioned a study to characterize the air emissions and to evaluate the potential health impact for on-site workers and off-site sensitive receptors (nearby residents and businesses).

In addition, odors had been occasionally detected off-property. The installation of the gas collection system and enclosed flare 2 years ago greatly decreased the incidence of off-site odors but did not totally eliminate them. This study included an evaluation of off-property ambient air concentrations of odorous compounds, and the potential frequency and duration of detectable odors.

SELECTION OF COMPOUNDS FOR STUDY

Landfill gas, composed mainly of methane and carbon dioxide, has trace (up to 1% total) amounts of potentially hundreds of compounds. The trace organic compounds are collectively referred to as non-methane organic compounds or NMOC. In addition, inorganic compounds such as hydrogen sulfide are present. Quantitative testing for all potential components is not feasible, practical or even desirable in terms of turn-around time or economics for an evaluation study. However, for estimating health and odor impacts, identification of the likely significant individual contributors is necessary.

The target compounds were selected based on the reported frequency of a compound's detection at other landfills weighted by its potential health or odor impacts.

Compounds representing both the aerobic and anaerobic stages of decomposition were included. Compounds, such as ethane, which are frequently detected in landfill gas but have low health risks and high odor detection thresholds were not included. Only volatile and semi-volatile compounds were considered.

A core target list (Table 1) of volatile and semi-volatile compounds was developed through a literature review of previous landfill gas composition studies, previous experience in studies of air emissions of landfill gas, review of California's landfill gas testing program, and input from the local regulatory community. (EPA 1991a; CARB 1986, 1989, 1990; California Waste Management Board 1988; Young and Parker 1983, 1984).

Carcinogens

The California Air Resources Board (CARB) conducted extensive testing of landfills in the early to mid-1980's. Ten carcinogenic compounds were chosen to be tracked as a result of the high frequency of their detection and their combined concentration and unit cancer risk (CARB 1990). The EPA (1991a) identified nine known or suspected carcinogens as present in MSW landfill emissions. Nine compounds from these groups are included on the target compound list for this study and are identified in Table 1 with a "c".

Odorous Compounds

Landfill gas odor is a composite odor with contributions from multiple compounds. Young and Parker (1983, 1984) identified two main groups of odorous compounds that are the most significant contributors to landfill gas odor. One group, which included alkyl benzenes and terpenes such as limonene, was consistently detected in the different types and ages of wastes. The second group was detected less consistently and includes esters, alcohols and organosulfurs. The esters and alcohols are formed during the early stages (aerobic) of waste decomposition. Representative compounds from both groups were included.

Target Compound List

In addition to the carcinogens and odorous compounds, other compounds commonly detected in landfill gas were included in the core target list (See for example EPA 1991a). The list of target compounds is given in Table 1 with associated HLV and odor thresholds, as well as the collection and analytical methods used to measure them.

MEASUREMENT TECHNIQUES

The target compounds form four general classes: volatile organics, semi-volatile organics, sulfur-containing gases, and water soluble compounds. Four collection and analysis techniques were needed to be able to measure all of the target compounds (see Table 1). The criteria for choosing the collection media were based on 1) the accuracy and precision of the method for the specific target compound; 2) a limit of detection of 2 ppbv or 25% of Connecticut's HLV for the compound, whichever was lower; 3) a preference for using the same collection technique for both the surface ambient air samples (dilute) and the landfill gas samples (concentrated); 4) minimal interference from the landfill gas matrix (methane/carbon dioxide/water); 5) the ability to concentrate a sample to obtain a lower detection limit; and 6) the applicability of the technique for target compounds not on the standard Method lists.

Volatile organic compounds were collected by adsorption on tenax, a Dow polymer, and analyzed by EPA Method 8240 (gas chromatography/mass spectrometry). Paired collection tubes, in sequence, were used. Separate analyses of the front and back tubes permitted an evaluation of the media adsorption efficiency. Incomplete adsorption or "breakthrough" is indicated by the detection of significant quantities (EPA 1990) of a compound on the back tube. For samples that meet the definition of breakthrough, the analysis is considered to be a lower limit.

Nine volatile compounds were not on standard TO1 (tenax) lists. The analytical laboratory performed desorption studies to determine the suitability of the tenax as a collection media.

Semi-volatile compounds were collected by adsorption on PUF/XAD (a layered media of polyurethane foam and amberlite resin) with subsequent analysis by EPA Method 8270 (gas chromatography/mass spectrometry). The alcohols and esters were collected by bubbling the sample through a water-filled impinger. The subsequent analysis was by direct injection gas chromatography with a flame ionization detector (GC/FID). This collection technique had the highest detection limit and probably the lowest precision and accuracy of the methods. The main interest in the alcohols and esters was for their potential odor nuisance and not any suspected potential health impacts and, therefore, the less precise method of water impingement was deemed acceptable for these compounds. Samples collected in Tedlar bags by EPA Method 18 ("bag in a

box") were analyzed for hydrogen sulfide, methyl mercaptan and ethyl mercaptan within 24 hours of collection (chemiluminescent detector).

Collection of On-Site Surface Ambient Air Samples

Samples of surface ambient air were collected from five grids on the surface of the landfill, using the CARB Method of Integrated Surface Sampling (CARB 1986) modified to this sites' requirements and collection methods. The general approach of this method is to measure the surface ambient air above a landfill within area grids by walking a set path through each grid over an hour period with portable sampling equipment. The grids at this site encompassed approximately 4650 m² (50,000 ft²) in area.

The grid traversing technique consisted of a control station, umbilical line and a mobile unit. The control station was located in the center of the grid, where sampling rates were monitored and meteorological data collected. One pump at the control station pulled all four samples by evacuating a surge tank to which all four sample lines were separately connected. Each sample line was fitted with an appropriately sized flowmeter with regulating valve, and a filter to protect each flowmeter from particulate interference. Figure 1 shows the sampling media layout.

The surface ambient air was sampled at locations considered to be worst-case areas. The general locations of the area sample grids were selected prior to the field work using the following criteria: the presence of visible leachate or residue, landfill gas odors noted in the past by the landfill manager, located on MSW-filled portion of the landfill (not the ash disposal areas), and out of the way of truck and contractor traffic or work zones.

A total of 0.26 inches of rain were recorded in the three weeks prior to sampling, with no precipitation in the nine-day period immediately previous to the landfill sampling efforts. The weather was partly to mostly cloudy, warm, humid and hazy. Winds were light and variable with extended periods of calm. The highest wind speed measured at any landfill sampling location was 4.5 mph. In general, the wind speeds were less than 2 mph. The CARB Integrated Surface Sampling technique specifies that average wind speeds must be less than 5 mph and the disposal site must be dry (no rain in preceding 72 hours).

Collection of Landfill Gas Samples

The landfill is equipped with a series of gas extraction wells located around most of the perimeter of

the landfill with an additional branch extending into the interior. In addition to vertical wells, there are horizontal wells which extend into the MSW placed in the interior of the landfill. These wells are connected to several common headers which join and lead to an exhaust fan and flare. The landfill gas samples were drawn from the collection system just prior to the enclosed flare. The sampling and collection techniques used for the gas collection system employed the same sampling media used for the surface ambient air samples. Three sets of samples were taken by TO-1, TO-13 and collected in the water impingers. Four samples were collected in Tedlar bags.

AIR DISPERSION MODELING

The modeling analyses were performed in accordance with the Connecticut Department of Environmental Protection's (CTDEP) "Ambient Impact Analysis Guideline" (AIAG)(1989) and the EPA's "Guideline on Air Quality Models" (revised 1987). Screening modeling was performed using the EPA-approved ISCST2. The refined modeling analysis was performed using the ISCSDFT model at the request of the CTDEP. ISCSDFT has since been formalized as ISCST3 and is an EPA recommended dispersion model. The air emissions from the landfill arise from a point source (the flare) and an area source (fugitive emissions from the landfill surface). A surrogate total emission rate was obtained using the following assumptions and procedures.

Air dispersion modeling requires the emission rate input in the form of a mass rate. The estimated potential maximum landfill gas collection system flowrate (the system design flowrate) was used to scale the concentration data to mass rate data. The fugitive emissions were estimated by assuming a collection system efficiency.

Landfill gas collection system efficiencies have not been measured. The collection efficiencies are estimated in various studies to be from 40% to 90% depending on the study (Barboza, 1992). The highest estimates are for closed and capped landfills. The background information document (EPA 1991a) for the proposed air emission standards for municipal waste landfills cites an estimate of 50-60% collection efficiency. The design estimate for the collection efficiency was 70%. However, for conservatism, 50% was used as the modeling input for the estimation of potential health impacts. The air pollutant emission control efficiency of the flare was assumed to be 98% (EPA 1991a) for every pollutant (the NMOC destruction efficiency). The ratio of emissions from the flare to emissions from the landfill

surface area for every air pollutant is 0.02. This emission distribution allowed the simplification of using a surrogate total emission rate of 51 g/s (1 g/s from the flare and 50 g/s from the surface area) in the modeling analysis. The impact for each specific pollutant was calculated from the ratio of the specific pollutant emission rate to the surrogate total (surface area plus flare) emission rate. The modeled dispersion of the flare emissions used actual flow rate data which is lower than the design capacity flow rate.

The modeling analysis used five years of meteorological data to predict worst-case impacts. The release elevation was taken to be the base elevation of the landform. The average height of the landform's top surface is 110 feet above the landfill base. This is a conservative assumption appropriate to an air toxics evaluation. Conservative assumptions were utilized when possible to overestimate the potential maximum health impacts. The modeling was performed on a 1-hour and 8-hour basis. The 1-hour modeling data was converted to a 30-minute basis (Hanna 1982, Turner 1970).

The purpose of the odor modeling was different than the modeling performed to estimate maximum potential ambient air concentrations for a health analysis. The odor modeling was designed to evaluate the potential of the current landfill gas emissions to cause an odor nuisance. It was appropriate to use more realistic data for the non-health related impacts. To that end, in order to obtain more realistic modeling results, three input assumptions were modified. The estimate of total landfill gas flowrates (gases emitted from the surface plus those collected and sent to the flare) was based on gas flowrates measured at the flare. The estimated design efficiency of the landfill gas collection system (70%) was used to approximate surface emissions. The release elevation was taken at 35% of the average height of the landform top surface. The 1-hour modeling data was converted to a 15-minute basis by multiplying the 1-hour results by 1.32 (Hanna 1982, Turner 1970). The output data from the air dispersion modeling was post-processed to provide information on the frequency and duration of potential off-site odors.

RESULTS

Analytical Results

The ambient air concentration results for the target compounds are summarized in Table 2. The surface ambient air concentrations are reported as measured. The concentration of the landfill gas constituents have been corrected to zero percent nitrogen (18.3% nitrogen was

detected in the landfill gas sampled from the collection system).

Several target compounds were detected in the field, trip or laboratory blanks suggesting contamination of either the sample media or of the collection or analysis process. The analytical data was not corrected (decreased) for the amount detected in the blanks for two reasons. The project was directed at making conservative assumptions. By not blank correcting, higher concentrations are reported than may be present, making this practice conservative. In addition, the multiple methods employed have separate requirements for permitting blank correction or not permitting it. See the EPA Handbook (1990) for example. As it was desired to treat all the data similarly, no blank correction was performed. It should be noted that for some compounds in the ambient air, such as limonene and naphthalene, the whole reported value appears to come from blank contributions.

The TO-1 compounds were collected with two tubes in series, each analyzed separately. Several compounds met the definition of breakthrough (EPA 1990) and their detected values are noted as ">" on the table.

The guidance for handling data near the detection limit given in an EPA Region III Technical Guidance Manual (1991b) was used. Briefly, the guidance states that if there is a reason to assume a compound might be present in a sample, one-half the detection limit should be reported for non-detects. Reporting at the detection limit would be too conservative an approach, while reporting zero is not conservative enough if there is reason to believe that the compound might be present.

In this program, if an analyte was detected in any sample taken - surface ambient air or landfill gas - and was not detected in another, one-half the detection limit was used for the non-detect surface ambient air samples. For additional conservatism in the air quality modeling, one-half the detection limit was entered for all non-detected target compounds as the input to the air quality modeling. This was done even for compounds not detected in any sample taken at the landfill.

COMPARISON WITH STANDARDS

Estimation of Health Impacts

The site is located in Connecticut and the pertinent regulatory standards are the Hazard Limiting Values (HLV) for hazardous air pollutants contained in the Regulations of the Connecticut State Agencies, Section

22a-174-29. These standards were designed as interim standards to protect human health while Ambient Air Quality Standards (AAQS) are developed. Connecticut's regulations divide these pollutants into three groups. Group 1 includes known and probable carcinogens. Group 2 includes teratogens, mutagens and compounds with weaker evidence for carcinogenicity. Noncarcinogenic hazardous substances form Group 3. The HLVs are derived by dividing the occupational threshold limit value for a compound by a reduction factor. The reduction factors are 200 for Group 1, 100 for Group 2, and 50 for Group 3.

The HLV's may or may not be reflective of true health risk as they are based on occupational threshold limit values as opposed to AAQS which are based on health effect studies. The HLVs were the standards used in this study because in Connecticut they are written into the regulations.

On-Site Surface Ambient Air. The ratios of the average surface ambient air concentrations (within the landfill) to their respective HLV are given in Table 3. For all compounds, this ratio is well below 1.

Off-Site Ambient Air. The ratios of the potential maximum off-site concentrations of the landfill gas constituents, obtained by the modeling, to their respective HLV are given in Table 3. For all compounds, this ratio is well below 1.

ESTIMATION OF ODOR IMPACTS

Odor detection thresholds were used whenever possible as opposed to odor recognition thresholds. An odor detection threshold is that concentration at which an odor is first perceived. An odor recognition threshold is that concentration at which the odor is both perceived and recognized. The majority of odor thresholds used in this study are detection thresholds taken from the American Industrial Hygiene Association (AIHA) technical critique (1989). For compounds not listed in the AIHA reference, the next source of odor thresholds utilized was the work by Young and Parker (1984). The rest of the odor thresholds were taken from the survey by Ruth (1986) using a geometric mean of the reported low and high values. The exception to this procedure is hydrogen sulfide whose odor detection limit was taken from Prokop (1992). The AIHA reference had an anomalous odor detection limit for hydrogen sulfide; it was greater than the recognition limit. For compounds with isomer forms, such as xylene, the lowest odor threshold for any isomer was used.

Connecticut defines odor nuisances and lists odor limit values for selected compounds in Section 22a-174-23 of its Regulations of Connecticut State Agencies. A compound exceeding its defined odor limit value is deemed a nuisance. Six of the 44 target compounds have a defined odor limit value.

Evaluation of On-Site Odors

The ratios of the average surface ambient air concentration within the landfill to the odor threshold are given in Table 3. All detected compounds are below their odor thresholds. Compounds that were detected in the landfill gas collection system samples but were not detected in the surface ambient air samples were evaluated at one-half their detection limit. Hydrogen sulfide, methyl mercaptan, ethyl propionate, and diisopropyl ether, at one-half their detection limit, were above their odor thresholds. This is consistent with the field testing during which odors were occasionally noted.

Evaluation of Off-Site Potential Odors

The ratios of the potential maximum off-site impacts of the landfill gas constituents to their respective odor thresholds are given in Table 3. For all compounds but hydrogen sulfide, this ratio is well below 1. For hydrogen sulfide, the potential maximum off-site impact is 2.8 times its odor detection threshold and is located near the property line. There are two locations with predicted incidences of off-site detectable odors; both are located adjacent to the property line, one to the north/northwest and one to the south/southeast. Review of the five years of modeling results shows the annual maximum frequency of incidences in these two locations range from 60 hours/year to 140 hours/year. Ninety percent of the incidences are 1 hour in duration. Impacts above the detection threshold lasting 2 hours or less are approximately 99% of the total hours.

CONCLUSIONS

Potential Health Impacts

This survey of air emissions from this landfill reveals no compounds present at their Hazard Limiting Value either on-site or off-site. Since the HLVs are calculated by multiplying the occupational threshold values by a reduction factor, these target compounds are below OSHA/NIOSH standards as well. It is concluded that the landfill presents no health risk from these compounds.

Conservative assumptions were made throughout this project. Therefore, the calculations and estimates

made are worst-case, and the actual maximum-impact concentrations are anticipated to be much less. If questions on health impacts persisted, those compounds with the highest relative risks (detected concentration divided by HLV) would have been recommended for formal risk assessment.

Potential Odor Impacts

All compounds detected in the ambient air sampled at the landfill surface were below their odor thresholds. Four of the compounds evaluated at one-half their detection limit were above their odor threshold. This is consistent with the occasional detection of "landfill gas odor" inside the landfill property boundary.

Detectable levels of hydrogen sulfide are predicted to occur infrequently at off-site locations; however these levels are below the odor limit value defined for hydrogen sulfide in the Regulations of Connecticut State Agencies Section 22a-174-23, Table 1. With on-going proper management, the landfill should not present off-site impacts at the odor nuisance level. Off-site detection of odors however will occasionally occur.

Acknowledgements

The authors thank the Air Quality Testing Group at Environmental Risk Limited for the field work, Zhenjia Li (Environmental Risk Limited) for the air dispersion modeling, Vlad Kloyzner (Environmental Risk Limited) for his assistance with the data reduction, Triangle Laboratories and Air Toxics Limited for their responsiveness throughout the test design, analysis and data reduction.

REFERENCES

American Industrial Hygiene Association, 1989, "Odor Thresholds for Chemicals with Established Occupational Health Standards."

Barboza, M. J., 1992, "Municipal Solid Waste Landfill Gas Emissions," Air Pollution Engineering Manual, Van Nostrand Reinhold, New York, pp. 863-872.

California Waste Management Board, October 1988, "Landfill Gas Characterization," Sacramento, CA.

EPA, January 1990, "Handbook Quality Assurance/Quality Control (QA/QC) Procedures for Hazardous Waste Incineration," EPA/625/6-89/023, PB91-145979, pp. 42-48.

EPA, March 1991a, "Air Emissions from Municipal Solid Waste

Landfills - Background Information for Proposed Standards and Guidelines," EPA-450/3-90/011a.

EPA, November 1991b, "Chemical Concentration Data Near the Detection Limit," Region III Technical Guidance Manual, EPA/903/8-91/001.

Hanna, Steven, R.; Briggs, Gary A.; Hosker, Jr., Rayford P., 1982, "Handbook on Atmospheric Diffusion," Technical Information Center, U.S. Department of Energy, pp. 33-34.

Prokop, W. H., P.E., "Odors," Air Pollution Engineering Manual, Van Nostrand Reinhold, New York, pp. 147-154.

Ruth, Jon H., March 1986, "Odor Thresholds and Irritation Levels of Several Chemical Substances: A Review," Am. Ind. Hyg. Assoc. J. (47) pp. A142-A151.

State of California, Air Resources Board, December 18, 1986, "Testing Guidelines for Active Solid Waste Disposal Sites."

State of California, Air Resources Board, Stationary Source Division, June 1989, "The Landfill Gas Testing Program: A Second Report to the California Legislature."

State of California, Air Resources Board, Stationary Source Division, September 13, 1990, "The Landfill Gas Testing Program: Data Analysis and Evaluation Guidelines," Sacramento, CA.

Turner, D. Bruce, "Workbook of Atmospheric Dispersion Estimates," U.S. Department of Health, Education and Welfare, Cincinnati, OH, PB-191-482, pp. 37-38.

Young, P.J., and Parker, A., 1983, "Identification and Possible Environmental Impact of Trace Gases and Vapours in Landfill Gas", Waste Management & Research, Vol. 1, 213-226.

Young, P.J., and Parker, A., May 7, 1984, "Origin and Control of Landfill Odors," Chemistry and Industry, pp. 329-333.

Table 1
TARGET COMPOUND LIST

COMPOUND	CAS Number	HLV (µg/m ³) 8h ZZA-174-29	RCSA TABLE 29-3	Analytical Method	ODOR THRESHOLD (µg/m ³)	ODOR ¹ LIMIT VALUE (µg/m ³)
1-Butanol	71-36-3	6000	3	W	3700	
1,1-Dichloroethane	75-34-3	8000	3	A	601000	
1,1,1-Trichloroethane	71-55-6	36000	3	A	2180000	
1,1,2-Trichloroethane	79-00-5	225	1	A	not found	
1,1,2,2-Tetrachloroethane	79-34-5	34.4	1	A	51000	
1,2-Dichlorobenzene	95-50-1	--	3	A	4280	
1,2-Dichloroethane	107-06-2	20	1	A	107000	
1,2-Dichloropropane	78-87-5	7000	3	A	1220	
1,4-Dichlorobenzene	106-46-7	9000	3	A	730	
2-Butanol	78-92-2	8100	3	W	9870	
2-Butanone	78-93-3	11800	3	A	48000	51000
4-Methyl-2-pentanone	106-10-1	4000	3	A	3870	
Acetone	67-64-1	11800	3	A	150000	
Acrylonitrile	107-13-1	22	1	A	3530	
Benzene	71-43-2	150	1	A	198000	
Butylbenzene, total	71-15-0	60	3	A	100	
Carbon disulfide	56-23-5	300	2	A	748	
Carbon tetrachloride	106-90-7	7000	3	A	1610000	
Chlorobenzene	67-66-3	250	1	A	6080	
Chloroform	156-60-5	15800	3	A	954000	
cis-1,2-Dichloroethane	108-20-3	21000	3	A	25800	
Dibutyl ether	64-17-5	38000	3	W	70.0	
Ethanol	105-54-4	20	1	W	345000	
Ethyl mercaptan	75-08-1	NL	3	S	3.00	1.08
Ethyl propionate	105-37-3	NL	3	W	0.904	
Ethylbenzene	100-41-4	8700	3	W	100	
Hydrogen sulfide	7789-08-4	280	3	S	200	
Methyl butyl acrylate	623-42-7	NL	3	S	0.71	6.36
Methyl methacrylate	74-93-1	20	1	W	5.00	
Methylene chloride	75-09-2	7000	3	S	1.08	2.0
Naphthalene	91-20-3	1000	3	B	203	
Propylbenzene, total	105-66-8	4800	3	A	160	
Propyl butyrate	106-38-5	NL	3	W	100	
Propyl propionate	127-18-4	1700	1	W	100	
Tetrahydrofuran	108-88-3	7500	3	A	324000	
Toluene	56-82-5	15800	3	A	6130	48000
trans-1,2-Dichloroethane	79-01-6	1350	1	A	25800	42100
Trichloroethene	75-60-4	112000	3	A	448000	
Trichloroethylene	2951-13-7	2500	3	A	181000	
Trimethylbenzene, total	75-01-4	50	1	A	11000	
Vinyl chloride	1330-20-7	6680	3	A	36800	
Xylenes, total	5989-27-5	NL	3	A	2740	
(±)Limonene		NL	3	B	57.0	

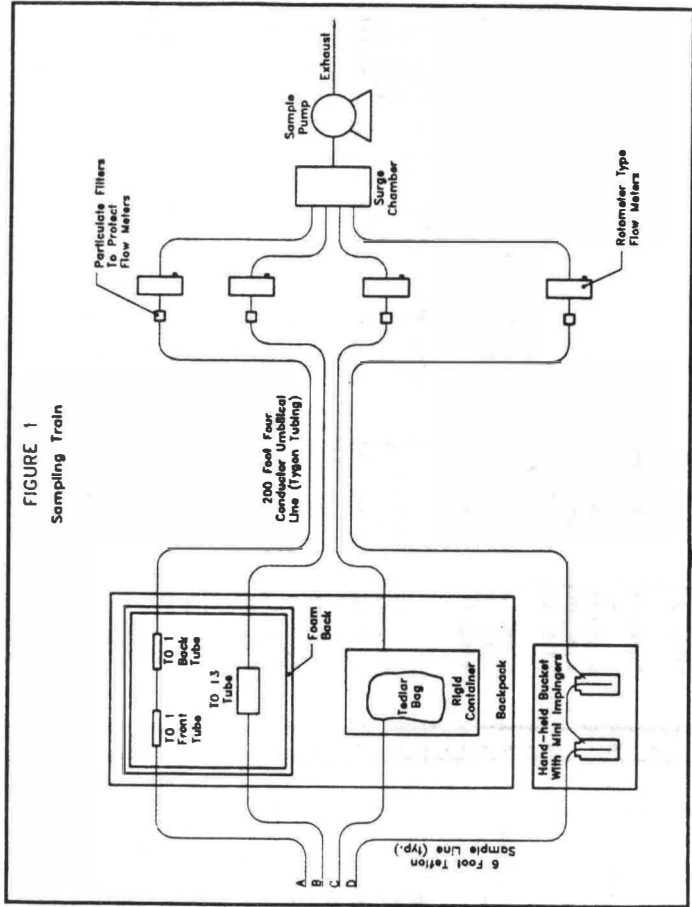


FIGURE 1
Sampling Train

1. The Hazard Limiting Values (HLV) for hazardous air pollutants are given in Tables 29-1, 2, 3 of Section 22a-174-29 of the Regulations of the Connecticut State Agencies (RCSA).
 2. The Odor Limit Value, 15 minute average is given in Table 29-1 of RCSA Section 22a-174-23.
 3. EPA (1901) or CARB (1990) landfill gas carcinogens list.
 NL: Not listed in Tables 29-1, 29-2, 29-3 of the Regulations of the Connecticut State Agencies.
 Section 22a-174-29.
 @: HLV is given for 1,2-Dichloroethane
 --: Compound is listed in HLV tables but no HLV is given.

COLLECTION METHOD / MEDIA ANALYTICAL METHOD

- A: TO-1 / Tenax / Modified EPA 8240 Volatiles
- B: TO-13 / XAD-2 / PUF / Standard EPA B270 PAH
- W: Water-filled Impingers / Water / Water Soluble Organics
- S: EPA 18 / Tedlar bags / ASTM D-5504 / Reduced Sulfur Compounds

Table 2
MONITORED CONCENTRATIONS

COMPOUND	CAS Number	Surface Ambient Air	Landfill Gas
		$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$
1-Butanol	71-36-3	0.077	77.997
1,1-Dichloroethane	75-34-3	1.968	>514.706
1,1,1-Trichloroethane	71-55-6	0.189	145.113
1,1,2-Trichloroethane	79-00-5	0.189	1.467
1,1,2,2-Tetrachloroethane	79-34-5	0.063	0.977
1,2-Dichlorobenzene	95-50-1	1.063	0.063
1,2-Dichloroethane	107-06-2	1.594	1.063
1,2-Dichloropropane	78-67-5	3.330	1.594
1,4-Dichlorobenzene	106-46-7	2.162	1468.436
2-Butanol	78-92-2	12.497	30.749
2-Butanone	78-93-3	2.257	2023.567
4-Methyl-2-pentanone	108-10-1	0.148	2.257
Acetone	67-64-1	141	120.078
Acrylonitrile	107-13-1	7.532	8.913
Benzene	71-43-2	0.417	1613.311
Butylbenzenes, total	71-15-0	0.487	0.544
Carbon disulfide	56-23-5	0.535	>44.734
Carbon tetrachloride	108-90-7	0.077	2.299
Chlorobenzene	67-66-3	0.148	409.201
Chloroform	156-60-5	109	0.772
cis-1,2-Dichloroethane	108-20-3	141	>907.060
Diisopropyl ether	64-17-5	141	280.557
Ethanol	105-54-4	141	1838.691
Ethyl butyrate	75-08-1	141	33.106
Ethyl mercaptan	105-37-3	141	413.460
Ethyl propionate	100-41-4	1.931	542.277
Ethylbenzene	7783-06-4	1.419	20664.320
Hydrogen sulfide	623-42-7	2.001	40143.000
Methyl butyrate	74-93-1	6.229	30.749
Methyl mercaptan	75-09-2	2.713	1592.700
Methylene chloride	91-20-3	0.827	>246.832
Naphthalene	105-66-8	2.081	801.390
Propylbenzenes, total	106-88-3	13.424	1542.016
Propyl butyrate	560-59-0	0.155	26.035
Propyl propionate	79-01-6	0.383	33.106
Tetrachloroethene	127-18-4	2.081	351.417
Toluene	106-88-3	13.424	12828.765
trans-1,2-Dichloroethane	560-59-0	0.155	13.351
Trichloroethene	79-01-6	0.383	281.407
Trichlorofluoromethane	75-69-4	5.604	>372.567
Trimethylbenzenes, total	25551-13-7	3.818	7.673
Vinyl chloride	75-01-4	0.310	237.118
Xylenes, total	1330-20-7	5.477	17575.297
(+) Limonene	5989-27-5	>12.91C	>16.125

Table 3
COMPARATIVE SIGNIFICANCE OF MONITORED CONCENTRATIONS

COMPOUND	Ratio of Landfill Surface Ambient Air		Ratio of Predicted Maximum Off-Site Concentration	
	8-Hour HLTV	to	30-Minute HLTV	to
	Odor Threshold	to	8-Hour HLTV	to
1-Butanol	9.68E-06	1.29E-07	2.73E-06	1.05E-06
1,1-Dichloroethane	5.18E-05	9.09E-07	>1.35E-05	>1.30E-05
1,1,1-Trichloroethane			8.02E-07	7.69E-07
1,1,2-Trichloroethane			1.37E-06	1.31E-06
1,1,2,2-Tetrachloroethane			5.97E-06	5.72E-06
1,2-Dichlorobenzene			1.75E-05	1.67E-05
1,2-Dichloroethane			4.78E-06	4.59E-06
1,2-Dichloropropane	3.70E-04	4.54E-03	3.43E-05	3.29E-05
1,4-Dichlorobenzene	1.83E-04	4.50E-05	1.06E-06	1.02E-06
2-Butanol	1.06E-03	8.34E-05	3.80E-05	3.45E-05
2-Butanone	5.02E-02	4.17E-03	1.18E-07	1.14E-07
4-Methyl-2-pentanone	NL	NL	2.14E-06	2.05E-06
Acetone	8.12E-03	6.50E-04	8.51E-05	8.16E-05
Acrylonitrile	1.78E-03	3.32E-07	2.26E-03	2.17E-03
Benzene	1.11E-05	1.27E-05	>1.57E-04	>1.50E-04
Butylbenzenes, total	9.35E-06	5.73E-06	1.61E-06	1.54E-06
Carbon disulfide	5.18E-03	1.55E+00	1.23E-05	1.18E-05
Carbon tetrachloride	3.70E-03	4.08E-04	6.48E-07	8.22E-07
Chlorobenzene	NL	NL	>1.21E-05	>1.18E-05
Chloroform	2.22E-04	9.06E-03	2.81E-06	2.69E-06
cis-1,2-Dichloroethane	5.07E-03	2.00E+00	1.02E-05	9.73E-06
Diisopropyl ether	NL	NL	NL	NL
Ethanol	1.41E+00	1.41E+00	4.34E-03	4.10E-03
Ethyl butyrate	2.22E-04	9.06E-03	NL	NL
Ethyl mercaptan	5.07E-03	2.00E+00	4.99E-04	4.78E-04
Ethyl propionate	1.00E-01	1.85E+00	3.01E-02	2.89E-02
Ethylbenzene	8.90E-04	1.10E-05	NL	NL
Hydrogen sulfide	2.71E-03	1.34E-02	1.67E-02	1.60E-02
Methyl butyrate	1.69E-04	5.17E-03	>7.41E-06	>7.10E-06
Methyl mercaptan	1.22E-03	6.42E-06	1.68E-04	1.61E-04
Methylene chloride	1.79E-03	2.19E-03	6.61E-05	6.34E-05
Naphthalene	9.81E-06	6.02E-06	NL	NL
Propylbenzenes, total	2.84E-04	8.56E-07	NL	NL
Propyl butyrate	5.06E-05	3.13E-05	NL	NL
Propyl propionate	1.53E-03	3.47E-04	NL	NL
Tetrachloroethene	6.20E-03	8.43E-06	4.34E-05	4.16E-05
Toluene	6.31E-04	2.00E-03	3.59E-04	3.44E-04
trans-1,2-Dichloroethane	NL	>2.26E-01	1.77E-07	1.70E-07
Trichloroethene	NL	NL	4.38E-05	4.20E-05
Trichlorofluoromethane	NL	NL	>3.49E-06	>6.7E-07
Trimethylbenzenes, total	6.31E-04	2.00E-03	6.45E-07	6.18E-07
Vinyl chloride	NL	>2.26E-01	9.96E-04	9.55E-04
Xylenes, total	NL	NL	4.25E-04	4.08E-04
(+) Limonene	NL	>2.26E-01	NL	NL

F:\USER\JECU\Z\ASME_2_3.WKS

Comments for Tables 2 and 3:
 * Not detected in either the landfill surface ambient air or landfill gas.
 # Detected only in one or more samples of landfill gas. One-half the detection limit is reported here.
 > One or more samples met the definition of breakthrough (EPA Method 8240).
 F,T,L: Compound detected in field, trip, lab blank, respectively.
 NL: Not listed in the HLTV tables (Regulations of the Connecticut State Agencies, Section 22a-174-20).
 -: Listed in the HLTV tables but no HLTV is given for this compound.

- The landfill gas concentrations are corrected to 0% nit. gen.
 - The landfill gas concentrations were used as input to dispersion modeling.
 Non-detected samples are listed at one-half their detection limit.
 Shaded entries contain ratios greater than 1.