TECHNICAL GUIDANCE FOR CORRECTIVE MEASURES - SUBSURFACE GAS

Prepared For:
Land Disposal Branch
Office of Solid Waste
U.S. Environmental Protection Agency
Washington, D.C. 20460

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March 28, 1985

File No. 28286-12
LC 89

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SECTION 1

INTRODUCTION

1.1 PURPOSE

This manual is intended to provide technical guidance for EPA and authorized State personnel in assessing the needs for corrective action, reviewing permit applications, and writing permits for hazardous waste facilities. Its primary function is to assist in the assessment of the potential for subsurface gas generation and migration from these facilities. In addition, it provides a framework to States, EPA, and facility owners or operators to identify whether subsurface gas is migrating or will likely migrate beyond the facility boundary or into on-site structures at concentrations that are threats to human health and the environment. If there is known or probable migration of this kind, then technically sound corrective action will be required.

The discussion in this section addresses current regulatory/ statutory requirements pertaining to subsurface gases, the definition of a release, and the types of solid waste management units at which a release can occur. Section 2 is an overview on factors that impact subsurface gas generation and migration. Section 3 provides methods to identify a subsurface gas release by the presence of specific hazardous waste constituents. This section summarizes the above into a checklist for the permit writer, providing evaluation of the presence or potential for a release based on the type of unit, existing site data, the potential for subsurface gas release, existence of control or systems, and other factors. The checklist assists the permit writer in identifying sites that require actions, emergency response, Remedial Investigation/Health Assessment, or corrective measures. Section 4 describes criteria for emergency situations and related actions and describes procedures for Remedial Investigations. Section 5 describes approaches to corrective measures such as monitoring, treatment, and control systems that could be implemented for subsurface gas releases.

1.2 REGULATORY/STATUTORY REQUIREMENTS

Releases of subsurface gases from hazardous waste facilities can result in threats to human health and the environment. Potential threats include accumulations of explosive or flammable gases, development of oxygen-deficient atmospheres in enclosed areas, possible acute or chronic health effects, and impacts on local plant and animal communities. The current regulatory/statutory requirements pertaining to these threats are summarized below.

Concentration limits for subsurface gases released from a solid waste management facility (applicable to all RCRA Subtitle D facilities) are established in 40 CFR Part 257.3-8(a). The levels for explosive gas concentrations are not to exceed:

1. The lower explosive limit; i.e., 5 percent methane, at the property boundary, and

2. 25 percent of the lower explosive limit, i.e., 1.25 percent methane, in facility structures.

These limits were designed to address methane generation and migration from landfills and open dumps and do not apply to hazardous waste (Subtitle C) or deep well injection facilities subject to regulation under 40 CFR Part 146 under the Safe Drinking Water Act.

Hazardous waste facilities must minimize subsurface gas releases and are required, under 40 CFR Part 264.31, to:

> "be designed, constructed, maintained, and operated to minimize the possibility of a fire, explosion, or any unplanned sudden or non-sudden releases of hazardous waste or hazardous waste constituents to air, soil, or surface water which could threaten human health or the environment."

The 1984 Amendments to RCRA provide additional authority for corrective action at facilities for which permits are being sought and for facilities with interim status under Section 3005(e). The amendments address: (1) continuing releases at permitted facilities; (2) corrective action beyond facility boundaries; (3) financial responsibility for corrective action; and (4) interim status corrective action orders.

EPA is to require corrective action in response to a release of hazardous waste from any solid waste management unit (SWMU) to the environment regardless of when the waste was managed. Its authority encompasses releases to all media, e.g. air, surface water, and ground water, and specifically includes releases to the unsaturated soil zone. This applies to all SWMU's, including former or existing nonregulated units, existing regulated units, and new units. While the regulatory requirements cover all SWMU's, this document will focus exclusively on those units exhibiting a potential for subsurface gas releases that are a threat to human health and environment.

1.3 DEFINITION OF A RELEASE

1.3.1 Constituents of Concern

A subsurface gas release from a SWMU is defined as having occurred when the concentration of a "constituent of concern" exceeds a specified level when measured in the unsaturated soil at the property boundary or within any structure on the hazardous waste facility. In the context of this document, a constituent of concern is (1) methane or (2) a compound, specified in 40 CFR Part 261 or in Appendix VIII, with a vapor pressure at 20°C that exceeds 0.1 mm Hg.

The components of a subsurface gas release will vary in concentration depending on the relative amounts of constituents volatilized by biological decomposition, chemical reactions, and physical degradation. By far, the predominant subsurface gas of concern from landfill SWMU's is methane. Methane is included in the grouping of constituents of concern due to its volatility, explosive properties, and frequency of detection in subsurface gases. The methane concentration limits specified to identify a subsurface gas release are those limits defined for explosive gases in 40 CFR Part 257.

The other constituents of concern (besides methane) are specified as toxic, corrosive, ignitable, or reactive in 40 CFR Part 261 or in Appendix VIII and are commonly termed volatile hazardous waste compounds because of their relatively high vapor pressures. A worker exposure level established by OSHA for each of these hazardous compounds will serve as the concentration limit to define a subsurface release. In summary, the concentration limits for identifying releases are shown in Table 1-1. Table 1-2 presents a specific listing of the constituents of concern by

TABLE 1-1. CONCENTRATION LIMITS TO DEFINE A RELEASE

Constituent Of Concern	Concentration Limit (equal to or greater than)	Applicable Location
Methane	5% in air	Soil at facility property boundary
Methane	1.25% in air	Within any structure on the facility
Compounds for which an exposure level has been established, recommended or adopted.	PEL or alternative concentration*	Soil at facility property boundary or within any structure on the facility.
Other compounds.	To be established	Same as above

* A PEL is the Permissible Exposure Limit as established by OSHA, in 29 CFR 1910.1 and is the 8-hour, work-shift, time-weighted average (TWA) level. For other constituents of concern for which a PEL has not been established by OSHA, the NIOSH recommended level is to be used. NIOSH recommended levels may be found in NIOSH Publication No. 78-210, September 1978. If no NIOSH recommended level is published, the current Threshold Limit Value - Time Weighted Average (TLV-TWA) adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) is to be used.

TABLE 1-2. CONSTITUENTS OF CONCERN

Compound Name	Synonym	Chemical Abstract System Number	EPA Hazardous Waste Number	PEL (ppm)	Vapor Pressure (mm HG) @ 20 degrees C
Maleic anhydride	2,5-Furanedione	108-31-6	U147	0.25	0.2
2-Methylaziridine	Propylene amine	75-55-8	U194	2	N/A
Methyl bromide	Bromomethane	74-83-9	U029	5	> 760
Methyl chloride	Chloromethane	74-87-3	U045	100	> 760
Methane	--	74-82-8	None	N/E	> 760
Methyl ethyl ketone	2-Butanone	78-93-3	U159	200	70
Methylene chloride	Dichloromethane	75-09-2	U080	500	354
Methyl cydrazine	--	60-34-4	P068	0.2	36
Methyl isocyanate	--	624-83-9	P064	0.02	346
Naphthalene	White tar	91-20-3	U165	10	< 1
Nickel carbonyl	--	13463-39-3	U073	0.001	321
Nitric oxide	Nitrogen monoxide	10102-43-9	P076	25	> 760
Nitrogen dioxide	--	10102-40-0	P078	5	720
Phenol	Carbolic acid	108-95-2	U188	5	0.4
Phosgene	--	75-44-5	P095	0.1	> 760
Phosphine	Hydrogen phosphide	7803-51-2	P096	0.3	> 760
Pyridine	--	110-86-1	U196	5	18
Tetrachlorobenzene	--	12408-10-5	U207	N/E	< 1
1,1,2,2-Tetrachloroethane	Acetylene tetrachloride	79-34-5	U209	5	8
1,1,1,2-Tetrachloroethane	--	630-20-6	U208	N/E	8
Tetrachloroethylene	Perchloroethylene	127-18-4	U210	100	10
Tetraethyl lead	--	78-00-2	P110	5	0.2
Toluene	Methylbenzene	108-88-3	U220	200	22
Tribromomethane	Bromoform	75-25-2	U225	0.5	5
Trichlorobenzene	--	12002-48-1	N/A	N/E	< 1
1,1,1-Trichloroethane	Methyl chloroform	71-55-6	U226	350	100
1,1,2-Trichloroethane	Vinyl trichloride	79-00-5	U227	10	18.8
Trichloroethylene (TCE)	Ethylene trichloride	79-01-6	U228	100	58
1,2,3-Trichloropropane	Allyl trichloride	96-18-4	N/A	50	3
Vinyl chloride	Chloroethylene	75-01-4	U043	1	> 760

N/E - Not Established
N/A - Not Available

TABLE 1-2 (Continued)

Compound Name	Synonym	Chemical Abstract System Number	EPA Hazardous Waste Number	PEL (ppm)	Vapor Pressure (mm HG) @ 20 degrees C
Acetaldehyde	Acetic aldehyde	75-07-0	U001	200	750
Acetone	2-Propanone	67-64-1	U002	1000	266
Acetonitrile	Cyanomethane	75-05-8	U003	40	73
Acrolein	Acrylic aldehyde	107-02-8	P003	0.1	214
Acrylonitrile	Propenonitrile	107-13-1	U009	2	83
Allyl alcohol	2-Propanol	107-18-6	P005	2	17
Allyl chloride	3-Chloropropene	107-05-1	N/A	50	295
Benzene	Bensol	71-43-2	U019	1	80
Benzl chloride	Alpha-chlorotoluene	100-44-7	P028	1	0.9
Bis(chloromethyl) ether	Syn-dichlorodimethylether	542-88-1	P016	N/E	N/A
Carbon disulfide	Carbon bisulfide	75-15-0	P022	20	300
Carbon tetrachloride	Tetrachloromethane	56-23-5	U211	10	91
Chloroacetaldehyde	2-Chloroethanol	107-20-0	P023	1	100
Chlorobenzene	Phenyl chloride	108-90-7	U037	75	9
2-Chloro ethyl vinyl ether	--	110-75-8	U042	50	N/A
Chloroform	Trichloromethane	67-66-3	U044	10	160
1,2- Dibromoethane	Ethylene dibromide	106-93-4	U067	20	11
Dibromomethane	Methylene bromide	75-09-2	U068	N/E	25
1,2-Dichlorobenzene	o-Dichlorobenzene	95-50-1	U070	50	1
1,3-Dichlorobenzene	m-Dichlorobenzene	25321-22-6	U071	N/E	2.5
1,4-Dichlorobenzene	p-Dichlorobenzene	106-46-7	U072	75	0.4
Dichlorodifluoromethane	Freon 12	75-71-8	U075	1000	> 760
1,1-Dichloroethane	Ethylidene dichloride	75-34-3	U076	100	182
1,2-Dichloroethane	Ethylene dichloride	107-06-02	U077	10	62
1,1-Dichloroethylene	Vinylidene chloride	75-35-4	U078	5	N/A
1,2-Dichloroethylene	Acetylene chloride	540-59-0	U079	200	220
1,2-Dichloropropane	Propylene dichloride	78-57-5	U083	75	41
1,1- Dimethylhydrazine	--	540-73-8	U098	0.5	103
Dimethyl sulfate	Methyl sulfate	77-78-1	U103	1	0.5
2,4- Dinitrotoluene	--	121-14-2	U105	185	1
Epichlorohydrin	1-Chloro-2,3-epoxypropane	106-89-8	U041	2	13
Ethylene imine	Aziridine	151-56-4	U054	0.5	N/A
Ethylene Oxide	1,2- Epoxy ethane	75-21-8	U115	50	> 760
Fluorene	--	86-73-7	P056	0.1	760
Formaldehyde	Methylene oxide	50-00-0	U122	3	1
Hydrazine	Diamine	302-01-2	U133	1	10
Hydrocyanic acid	Hydrogen cyanide	74-90-8	P063	10	620
Hexachloroethane	Perchloroethane	67-75-1	U131	1	0.2
Hydrogen sulfide	Hydrosulfuric acid	7783-06-4	U135	10	> 760
Iodomethane	Methyl iodide	74-88-4	U138	5	375
Isobutyl alcohol	Isobutanol	78-83-1	U140	50	9

compound name, synonym, EPA Hazardous Waste number, Chemical Abstract System (CAS) number, OSHA Permissible Exposure Limit (PEL), and vapor pressure. Table 1-3 provides further information about constituents of concern. It includes general descriptions of waste types that likely contain specific constituents of concern.

1.3.2 Indicator Constituents

The presence of individual constituents of concern in subsurface gases is often site-specific and dependent on factors discussed in the next section. Although variations in subsurface gas composition have been observed from different sites and different locations on the same site, some compounds are detected more frequently than others. Many of the compounds in Table 1-2 have not been reported in samples from subsurface gas monitoring, are not stored, treated, or disposed of in significant quantities at subsurface SWMU's, or are not likely to migrate and exceed PEL's due to physical or chemical properties. Thus monitoring for each of the constituents of concern will not be required to determine if a release has occurred. Instead, a screening procedure may be used to monitor for those compounds that the facility owner/operator or permit writer expects are migrating from the SWMU and pose a threat to human health and the environment.

TABLE 1-3. GENERIC COMPOUND DESCRIPTIONS

Compound Name	Synonym	EPA Hazardous Waste Number	Description
Acetaldehyde	Acetic aldehyde	U001	Distillation bottoms and by products from production of acetaldhyde from ethylene; chemical family is aldehyde.
Acetone	2-propanone	U002	Spent non-halogenated solvents; spent cleaning or spinnin solvent; spent paint, laquor, or varnish remover; chemica family is ketone.
Acetonitrile	Cyanomethane	U003	By-products from the hydrocarbon extraction of butadiene; by-products from the production of certain vegetable oils; chemical family is nitriles.
Acrolein	Acrylic aldehyde	P003	By-products from the manufacture and waste treatment of various pharmaceuticals, herbicides, and polymers, expecial polyurethane and polyester resins. Chemical family is aldehyde.
Acrylonitrile	Propenonitrile	U009	By-products from the manufacture and waste treatment of acrylic polymers and various semiconductive polymers. Chemical famiIiy is nitrile.
Allyl alcohol	2-propenol	P005	By-products from the manufacture and treatment of pharmaceuticals, herbicides, plasticizers, and glycerol. Chemical family is ester.
Allyl chloride	3-Chloropropene	N/A	By-products from the manufacture and treatment of epichlorohydrin; certain synthetic pharmaceuticals, and adhesives. Chemical family is halogenated hydrocarbon.
Benzene	--	U019	Chemical by-products from manufacture and waste treatment of the following chemical intermediates: ethylbenzene, dodecyclobenzene, and nitrobenzene. Chemical family is aromatic hydrocarbons.
Benzyl chloride	l-chlorotoluene	P028	By-products from the manufacture and waste treatment of photographic chemicals, quarternay (ammonium) agents, perfum and pharmaceuticals. Chemical famiIiy is halogenated aromat hydrocarbons.
Bis(chloromethyl) ether	Dichlorodimethyl ether	P016	Spent ion-exchange resins and laboratory reagents. Chemical family is ether.
Carbon disulfide	Carbon bisulfide	P022	Manufacturing by-products and/or sludge from the treatment of viscone rayon, cellophane, and veterinary medicines. Chemical family is sulfide.

Compound Name	Synonym	EPA Hazardous Waste Number	Description
Carbon tetrachloride	Tetrachloromethane	U211	Spent refrigerant and metal degreasing solvents. By-produ from the manufacture and waste treatment of various semi-conductors. Chemical family is halogenated hydrocarbon.
Chloroacetaldehyde	2-chloroethanol	P023	Various spent fungicides. Possible distillation by-products of acetaldehyde. Chemical family is aldehyde.
Chlorobenzene	Phenyl chloride	U037	Possible distillation by-products of phenol, chloronitro benzene, and aniline. Spent pesticide intermediates. Chemical family is halogenated aromatic hydrocarbons.
2-chloro ethyl vinyl ether	--	U042	Spent organic laboratory reagents. Chemical family is ether.
Chloroform	Trichloromethane	U044	Various spent refrigerants and propellants. By-products from the manufacture of insecticides and fluorocarbon plasti Spent analytical laboratory reagents. Chemical family is halogenated hydrocarbon.
1-2 Dibromomethane	Ethylene dibromide	U067	Spent organic intermediate. Chemical family is halogenated hydrocarbons.
Dibromomethane	Methylene dibromide	U068	Spent organic intermediate. Chemical family is halogenated hydrocarbons.
1,2-dichlorobenzene	o-dichlorobenzene	U070	Spent organic solvent, by-product from the manufacture of various dyes, insecticides, and metal polishes. Chemical familiy is halogenated aromatic hydrocarbons.
1,3-dichlorobenzene	m-dichlorobenzene	U071	By-products from the manufacture of insecticides. Chemical family is halogenated aromatic hydrocarbons.
Dichlorodifluoromethane	Freon 12	U075	Spent refrigerant. Chemical family is halogentaed hydrocarbon.
1,1-dichloroethane	Ethylidene chloride	U076	Spent organic solvent. Chemical family is halogenated hydrocarbon.
1,2-dichloroethane	Ethylene dichloride	U077	Spent organic solvent. By-product from manufacture of vinyl chloride, soaps, chelating agents, degreasers, and anti-knock gasoline. Chemical family is halogenated hydrocarbon.
1;1-dichloroethylene	Vinylidene chloride	U078	Spent organic solvents. By-product from the manufacture of perfumes, lacquers, and thermoplastics. Chemical family is halogenated hydrocarbon.

Compound Name	Synonym	EPA Hazardous Waste Number	Description
1,2-dichloroethylene	Acetylene chloride	U079	Spent organic solvent. By-product from the manufacture o perfumes, lacquers, and thermoplastics. Chemical family is halogenated hydrocarbons.
1,2-dichloropropane	Propylene dichloride	U083	Spent organic solvent. Gasoline component. By-products the manufacture of carbon tetrachloride, and various gums waxes, and resins. Chemical family is halogenated hydroca
1,1-dimethyl hydrazine	--	U098	By-products from the manufacture of various jet and rocket fuels. Chemical family is amine.
Dimethyl sulfate	Methyl sulfate	U103	By-product of the manufacture for various amine and pheno based compounds. Chemical family is alkyl sulfate.
2,4-Dinitrotoluene	--	U105	By-products of the manufacture of variouis dyes and explosives. Chemical family is aromatic hydrocarbon.
Epichlorohydrin	1-chloro-2,3-epoxy propane	U041	By-products of the manufacture of various epoxy and phenoxy resins. Chemical family is epoxide.
Ethylene imine	Aziridene	P054	By-products of the manufacturing in the following industries: pharmaceuticals, ion exchange and protective coatings, and surfactants. Chemical family is imines.
Ethylene oxide	1,2-epoxy ethane	U115	By-products from the manufacture of several glycols, surfactants and rocket propellant. Chemical family is oxirane.
Fluorine	--	P056	By-product from the manufacture of rocket fuels and various fluorocarbons. Chemical family is halogen.
Formaldehyde	Methylene oxide	U122	Spent laboratory reagents. By-products from manufacture of fertilizers, dyes, embalming fluids, disinfectants, and germicides. Chemical family is aldehyde.
Hexachloroethane	Perchloroethane	U031	Spent solvent and organic laboratory reagent. Chemical family is halogenated hydrocarbon.
Hydrazine	Diamine	U133	By-products from the manufacture of agricultural chemicals, rocket fuels, and metal plating solutions. Chemical family is amine.
Hydrocyanic acid	Hydrogen cyanide	P063	By-products from the manufacture of acrylates, cyanide salts dyes, and chelating agents. Chemical family is nitrile.

Compound Name	Synonym	EPA Hazardous Waste Number	Description
Hydrogen sulfide	Hydrosulfuric acid	U135	Spent laboratory reagent. By-product from the manufacture of elemental sulfur, sulfuric acid, and hydrochloric acid. Chemical family is sulfide.
Iodomethane	Methyl iodide	U138	Spent organic laboratory reagent. By-products from manufacture of various medicines. Chemical family is hydrogenated hydrocarbon.
Isobutyl alcohol	Isobutanol	U140	Spent organic laboratory reagent. Spent paint solvent. Chemical family is alcohol.
Maleic anhydride	2,5-Furanedione	U147	By-products from the manufacture of polyester and alkyd resins, pesticides, and paper. Chemical family is furan.
2-methylaziridine	Propylene amine	U194	Spent organic laboratory reagent. Chemical family is amine.
Methyl bromide	Bromomethane	U029	Spent organic laboratory reagent. By-product from the manufacture of various agricultural disinfectants.
Methyl chloride	Chloromethane	U045	Spent organic solvent. By-product from the manufacture of herbicides and gasoline additives. Chemical family is halogenated hydrocarbon.
Methane	--	None	Natural gas. Chemical family is hydrocarbon.
Methyl ethyl ketone	2-butanone	U159	Spent solvent. Spent organic laboratory reagent. Spent paint and wax remover. Chemical family is ketone.
Methylene chloride	Dichloromethane	U080	Spent solvent. Spent degreaser. Spent paint remover. Chemical family is halogenated hydrocarbon.
Methyl hydrazine	--	P068	Spent solvent. Spent or contaminated rocket fuel. Chemical family is amine.
Methyl isocyanate	--	P064	Spent chemical intermediate. Chemical family is nitrile.
Naphthalene	White tar	U165	Spent solvent. By-product from the manufacture of lubricants, fungicides, and explosives. Chemical family is aromatic hydrocarbon.
Nickel carbonyl	--	P073	By-product from the manufacture of various nickel coating Chemical family is carbonyl compound.

Compound Name	Synonym	EPA Hazardous Waste Number	Description
Nitric oxide	Nitrogen monoxide	P076	Spent chemical intermediate. Chemical family is oxide.
Nitrogen dioxide	--	P078	By-products from the manufacture of nitric acid. Chemical family is oxide.
Phenol	Carbolic acid	U188	Spent organic laboratory reagent. By-product from the manufacture of various dyes, pharmaceuticals, and phenol-based compounds. Spent solvent. Chemical family is phenol.
Phosgene	--	P095	Spent organic solvent. By-product from the manufacture of various isocyanates, carbonates, chloroformates, pesticides, and herbicides. Chemical family is ketone.
Phosphine	Hydrogen Phosphide	P096	Spent organic intermediate. Spent doping agent for solid state electronic components. Chemical family is phosphide.
Pyridine	--	U196	Spent solvent. By-product from manufacture of various vitamins, drugs, dyes, and fungicides. Chemical family is amine.
Tetrachlorobenzene	--	U207	Spent solvents. Found in dielectric fluids and electrical insulation. Chemical family is halogenated aromatic hydrocarbon.
1,1,2,2-tetrachloroethane	Acetylene tetrachloride	U209	Spent solvent. Spent degreaser. Spent organic laboratory reagent. By-product in manufacture of various insecticides
1,1,1,2-tetrachloroethane	--	U208	Spent solvent. Spent degreaser. Spent organic laboratory reagent. By-product in manufacture of various insecticides and photographic films. Chemical family is halogenated hydrocarbon.
Tetrachloroethylene	Perchloroethylene	U210	Spent dry cleaning solvent. Spent degreaser. By-product of manufacture of fluorocarbons. Chemical family is halogenated hydrocarbon.
Tetraethyl lead	--	P110	Used as a fuel additive. Chemical family is metal substituted hydrocarbon.
Toluene	Methyl benzene	U220	Spent solvent. Fuel additive. By-products from manufacture of resins, coatings, dyes, and explosives. Chemical family is aromatic hydrocarbon.
Tribromomethane	Bromoform	U225	Spent solvent. Organic intermediate. Chemical family is halogenated hydrocarbon.

TABLE 1-3 (Continued)

Compound Name	Synonym	EPA Hazardous Waste Number	Description
Trichlorobenzene	--	N/A	Spent solvent. By-products from manufacture of dyes, dielectric fluids, lubricants, and insecticides. Chemica family is halogenated aromatic hydrocarbon.
1,1,1-trichloroethane	Methyl chloroform	U226	Spent solvent. Spent metal degreaser. Chemical family is halogenated hydrocarbon.
1,1,2-trichloroethane	Vinyl chloride	U227	Spent solvent. Spent organic laboratory reagent. Chemical family is halogenated hydrocarbon.
Trichloroethylene	Ethylene trichloride	U228	Spent solvent. Spent refrigerant. Spent decreaser. Spent chemical intermediate. Chemical family is halogenated hydrocarbon.
1,2,3 Trichloropropane	Allyl trichloride	N/A	Spent solvent. Spent degreaser. Chemical family is halogenated hydrocarbon.
Vinyl chloride	Chloroethylene	U043	By-product from the manufacture of polyvinyl chloride and related polymers. Chemical family is halogenated hydrocarbons.

By products are defined as those compound(s), reacted or unreacted, found present in a non-product stream exiting the manufacturing process.

N/A : Not Available

A group of 16 indicator constituents of concern has been selected and is shown in Table 1-4. Monitoring for these 16 constituents may be used as a screening approach to the identification of a subsurface gas release. Table 1-4 includes methane, a compound without an OSHA PEL, and the other compounds that are primarily chlorinated hydrocarbons with PEL's in the range of 1 to 1,000 parts per million (ppm). These constituents were selected as indicators due to their presence in past subsurface gas releases from hazardous waste landfills that had received a wide variety of wastes.

Other compounds could be added to the indicator list depending on the type of SWMU, available site-specific data on construction, operations, monitoring, and spills, and inspections performed at the site. For example, if an underground storage tank contains acetaldehyde, it could be added to the indicator list for this specific SWMU. To be added to the indicator list, the compound should (1) be a constituent of concern (listed on Table 1-2); (2) be expected to migrate beyond the facility boundary or into on-site structures at concentrations exceeding the specified levels; and (3) pose a threat to human health and the environment.

1.4 TYPES OF SOLID WASTE MANAGEMENT UNITS

This document addresses SWMU's (1) at which only solid waste is or was managed, and that are located at treatment, stor-

TABLE 1-4. INDICATOR CONSTITUENTS OF CONCERN

Compound (Molecular Weight)	Synonym	RCRA Appendix VIII	Vapor Pressure (mm Hg at 20°C)	PEL (ppm)
1. Benzene (78)	---	X	75	1
2. Chloroform (119)	Trichloromethane	X	160	50
3. Dichlorodifluromethane (121)	Freon 12	X	>760	1,000
4. 1,1-Dichloroethane (99)	Ethylidene Chloride	X	182	100
5. 1,2-Dichloroethane (99)	Ethylene Dichloride	X	62	10
6. 1,1-Dichloroethylene (97)	Vinylidene Chloride	X	490	5
7. 1,2-Dichloroethylene (97)	---	X	220	200
8. Dichloromethane (85)	Methylene Chloride	X	350	500
9. Methane (16)	---		>760	*
10. 1,1,2,2-Tetrachloroethane (168)	---	X	8	5
11. Tetrachloroethylene (166)	Perchloroethylene	X	14	100
12. Toluene (92)	Methyl Benzene	X	22	200
13. 1,1,1-Trichloroethane (133)	Methyl Chloroform	X	100	350
14. 1,1,2-Trichloroethane (133)	Vinyl Trichloride	X	19	10
15. Trichloroethylene	TCE	X	58	100
16. Vinyl Chloride (62)	Chloroethylene	X	>760	1

* No PEL established. Levels for methane are not to exceed 5 percent at the property boundary or 1.25 percent in facility structures.

age, or disposal facilities seeking a RCRA Permit; and (2) that exhibit a potential for subsurface gas migration of methane or hazardous constituents at concentrations that pose a threat to human health or the environment. The applicable types of SWMU's are principally underground and are discussed below.

Underground units, (those designed for storage, treatment, or disposal of waste below grade and not open to the atmosphere) are the only units that have significant potential for subsurface gas releases. Gases generated in these units may migrate upwards or horizontally and can attain concentrations of concern to human health and the environment. For example, the methane in landfill gas can be explosive and is known to migrate through soils and along confining barriers such as ground-water tables, clay layers, synthetic liners, and compacted covers. Since gases in these units are generated well below the surface, horizontal migration prior to surface venting is possible.

Some SWMU's are essentially surface operations that extend below grade into shallow soils. Although gases may be generated in these units and migrate into the unsaturated soil zone, the potential for horizontal migration is low and a release is unlikely. Shallow subsurface gases will escape into the atmosphere as surface emissions unless prevented by barriers; e.g., paving, campaction, or installation of covers for closure. If gases are prevented from venting to the atmosphere, lateral migration may occur. Generally, this lateral migration is limited to the extent of the barrier. Therefore, while pathways do exist for subsurface gas releases beyond a property boundary, the potential for releases from shallow SWMU's is usually insignificant.

Although depth (underground versus shallow) is one of several considerations for determining release potential, the type of SWMU establishes potential migration pathways and the waste characteristics create the driving forces for subsurface gas movement. Figures 1-1 and 1-2 illustrate some potential path- ways from a few example SWMU's. It should be noted that for most SWMU's, it is unlikely that a release would ever occur because gases generated in the units would be more likely to vent to the atmosphere than to concentrate in the unsaturated soil. Therefore, the types of SWMU's of concern for subsurface gas releases are listed below.

- Landfills

- Sites closed as landfills

- Underground tanks

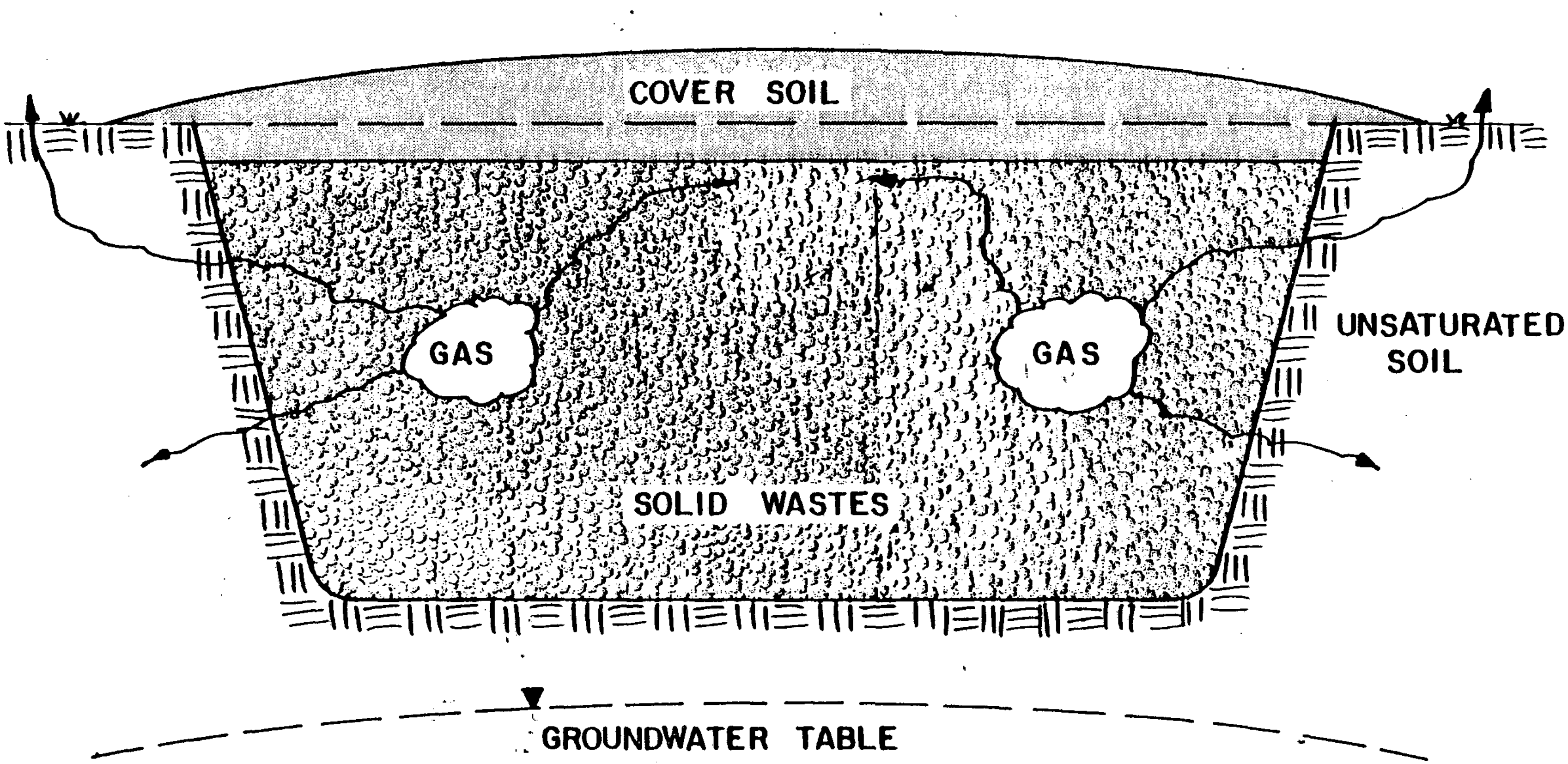


Figure 1-1. Subsurface gas generation/migration in a landfill.

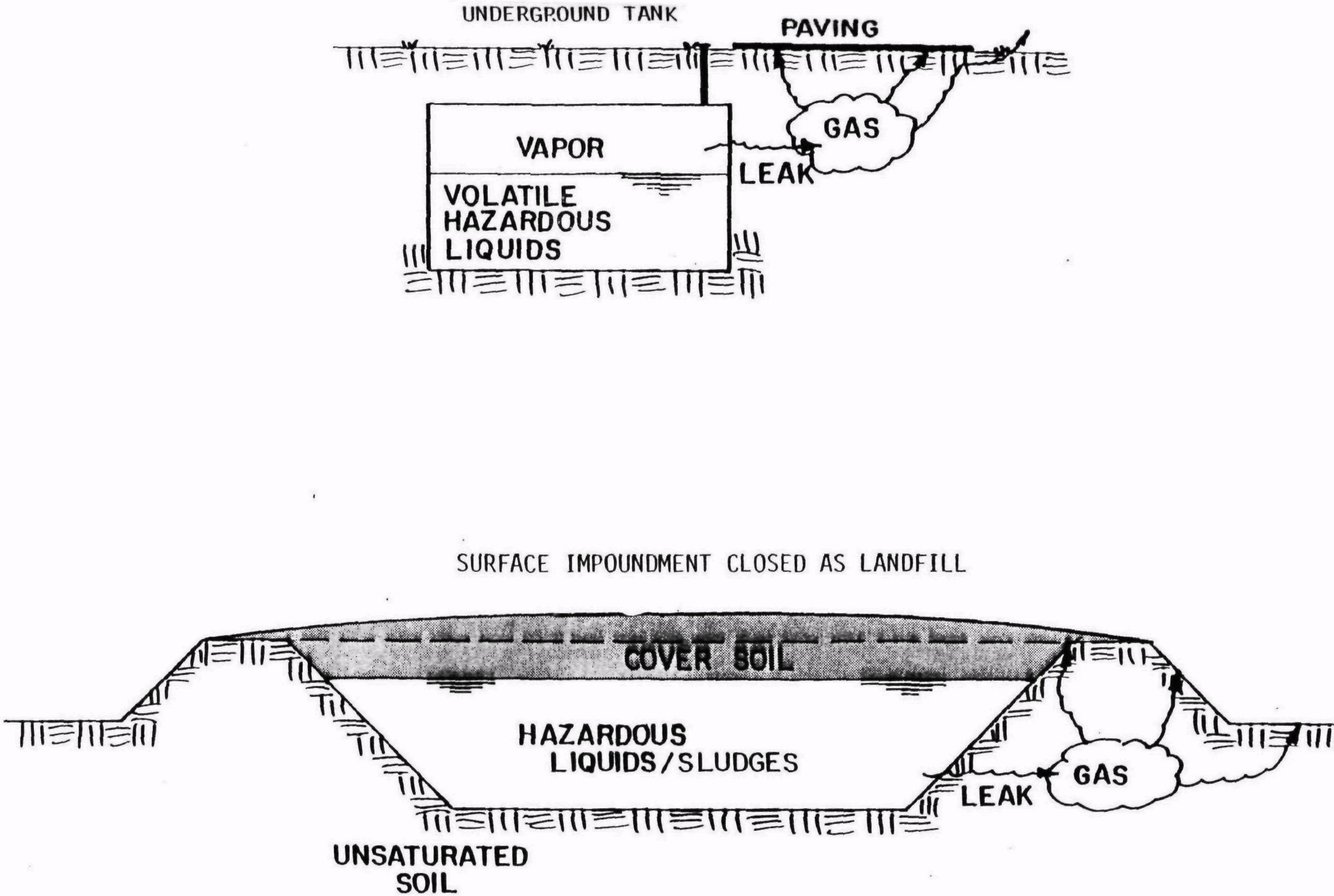


Figure 1-2. Subsurface gas generation/migration from tanks and units closed as landfills.

1.4.1 Landfills

Landfills are the most likely SWMU's to generate subsurface gases resulting in a release. The underground deposition of decomposable solid waste with or without hazardous constituents provides a large source of gas and a driving force that can carry other gases venting to the atmosphere and/or migrating horizontally as a subsurface gas. The closure of landfills with impermeable caps is one means of retarding these landfill gases from escaping as surface emissions. In these instances, a large percentage of those gases migrate laterally, possibly causing significant accumulations in facility structures or at property boundaries.

1.4.2 Sites Closed As Landfills

Inactive SWMU's that have been closed as landfills may generate subsurface gases. These sites include closed surface impoundments or waste piles containing decomposable or volatile wastes with in-place impermeable covers. Similar to landfills, gases generated in sites closed as landfills may migrate laterally, possibly causing significant accumulations. However, closed surface impoundments and waste piles generally contain small quantities of decomposable and volatile wastes and are at shallow depths. Thus, significant gas migration and subsequent subsurface gas releases are unlikely.

1.4.3 Underground Tanks

Underground tanks will not normally generate subsurface gases. Only if the tank is leaking is there an opportunity for a gas to migrate into the unsaturated zone. Since volatile liquids are often stored in underground tanks, the potential for a subsurface gas release exists. However, anticipated gas leaks under these conditions would be small and probably insignificant.

In summary, landfills, sites closed as landfills, and underground tanks are the only SWMU's with characteristics conducive to subsurface gas migration problems. That is, the depth of waste deposition or storage is adequate to allow subsurface gas migration and a source of subsurface gas is present (generated by decomposition of organic wastes or volatilization).

Other types of SWMU's, such as land treatment units, active surface impoundments, and injection wells, do not exhibit a potential for gas migration and are not applicable to subsurface gas releases. For instance, in land treatment units the production of methane gas is absent and wastes are incorporated into the soil surface to allow free venting of any generated gases to the atmosphere. Where gases are generated within an active surface impoundment, they likely will vent across the liquid surface to the atmosphere rather than migrate through impoundment walls. While it is possible that gases could be generated from leaking leachate or volatile liquids from the unit, significant subsurface gas migration and accumulation are unlikely.

SECTION 2

GENERATION AND MIGRATION OF SUBSURFACE GASES

The generation and migration of subsurface gases are two distinct processes that contribute to the potential for a release from an SWMU. While gas generation centers primarily on waste types, and the type of SWMU, gas migration concerns pathways and barriers for movement through the surrounding soils. This section reviews factors that influence and promote subsurface gas generation and migration of those SWMU's where releases may occur.

2.1 GAS GENERATION

2.1.1 Biological Decomposition

Gas generation and accumulation in SWMU's occurs by biological, chemical, and physical decomposition of the disposed or stored wastes. The type of SWMU relates to the extent of biological decomposition and subsequent gas generation from a given waste. For instance, biological decomposition is significant in most landfills and sites closed as landfills due to anaerobic microbial degradation of organic wastes. However, biological decomposition is not a gas generating process in underground tanks where volatile liquids are stored.

Waste types will significantly influence the rate of gas generation via biological decomposition and the ultimate amount of gas produced at an SWMU. Generally, the amount of gas generated in a landfill is directly proportional to the amount of organic matter present. In a landfill, the types of organic wastes can be divided into rapid and slow decomposables. A high percentage of rapid decomposables (such as food waste, sewage sludges, and garden waste) will result in gas generation shortly after burial and high initial yields. Slow decomposables include paper, cardboard, wood, leather, some textiles, and several other organic components. Inorganics and inerts such as plastics, man-made textiles, glass, ceramics, metals, ash, and rock do not contribute to biological gas production. At sites closed as landfills, waste types that undergo biological decomposition might include bulk organic wastes, food processing sludges, treatment plant sludges, and composting wastes.

In addition to waste type, how the wastes are managed (stored, treated, or disposed) and the specific waste characteristics will both impact rates of gas generation from SWMU's. Other factors important to biological production include:

- waste characteristics,
- unit design,
- unit operations.

Waste characteristics can enhance or inhibit the rate of microbial activity. For instance, high moisture content (in the as-received waste or through percolation, or both) will provide optimal conditions to enhance anaerobic decomposition. Other enhancement characteristics include adequate buffer capacity and neutral pH, sufficient nutrients (nitrogen and phosphorous), and mesophilic temperatures. Inhibiting characteristics include the presence of high or low pH, sulfur, and soluble metals, perhaps due to the disposal of nonhazardous industrial wastes.

Unit design at landfills and sites closed as landfills can promote gas generation. Waste depth, fill configuration, and cover soils are important. Specifically, deep landfills are better gas producers than shallow ones. They have a proportionately larger anaerobic zone, better insulation and compaction, and a better opportunity to confine generated gases. Fill configuration and landfill location impact gas production. Deep landfills, such as trench fills or canyon fills, trap gas along confining sidewalls and bottom bedrock or ground water. Conversely, mound or shallow landfills have large surface areas through which gases can vent. Daily, interim, and final cover soils can retain gases of biological decomposition within the landfill. Tight cover soils (e.g., clays) impede vertical migration of gases better than permeable soils.

Unit operations can have a significant impact on potential gas generation. Methods and procedures used to segregate and isolate inert wastes, to prevent moisture infiltration, to compact and increase the density of the waste, and to minimize or prevent mixing of waste types can affect resultant releases of subsurface gases. Biological decomposition can be inhibited by containers and containment devices, such as drums, tanks, liners, soil berm dividers, and daily covers. When organic material is landfilled under anaerobic conditions, it is converted by microbial action primarily into carbon dioxide and methane. Hydrogen, ammonia, aromatic hydrocarbons, halogenated organics, and hydrogen sulfide are also present as gases but usually in trace amounts. Due to the large volumes of decomposable wastes deposited in landfills, landfill gas yields can be high. The primary gases of concern resulting from biological decomposition are methane (due to its explosive properties) and other volatile organics that may be present in amounts that pose a threat to human health or the environment. Other volatile organics that are frequently detected in landfill gases were presented in Table 1-4.

2.1.2 Chemical Decomposition

Chemical decomposition of waste is not a significant gas-generating process in most SWMU's. However, gas production by chemical reaction can result from the disposal or storage of incompatible wastes. In landfills, sites closed as landfills, and underground tanks, gas production from chemical reactions that pose a threat to human health and environment is not expected under normal unit operations. Waste types can influence the potential for chemical reactions to occur. Reactive or ignitable wastes can produce explosive or heat-producing reactions, resulting in rapid production of gases, increased pressures, and increased temperatures. Volatile liquids stored in underground tanks may have a significant potential for gas production by chemical reaction. However, most waste types deposited in landfills and sites closed as landfills are not amenable to significant chemical reactions and regulations require special handling for reactive wastes to minimize these problems.

In addition to waste type, how the wastes are managed will affect the potential for significant chemical reactions and subsequent gas production. In particular, the proper design and operation (e.g., pressure-relief valves and leak detection systems) of underground tanks will prevent the occurrence of chemical decomposition by reaction. In a landfill under acidic conditions, a strong oxidizing agent can react with organic wastes to produce carbon dioxide and ammonia. Other chemical reactions that might occur in SWMU's are difficult to predict. As a result, the primary gases of concern from chemical decomposition may include all of the constituents of concern listed in Table 1-2.

2.1.3 Physical Decomposition

The type of SWMU relates to the potential for physical decomposition and subsequent gas generation from a given waste. In the context of this document, physical decomposition includes volatilization and combustion. Volatilization of compounds is most likely in underground tanks containing volatile liquids where a liquid and vapor-phase equilibrium is established in the tank. Volatilization occurs to a lesser extent in landfills and sites closed as landfills, primarily during waste application or other exposure to air. Sublimation is the direct conversion of solids to gases without a liquid phase. This occurs in landfills but generation via this mechanism is considered insignificant.

Combustion processes can actively contribute to subsurface gas generation. For example, underground fires are encountered at landfills. Combustion processes resulting in subsurface gas emissions are not expected in sites closed as landfills (that were previously surface impoundmentrs or waste piles) or underground tanks.

Waste types will influence the potential for physical decomposition to occur via volatilization and combustion. Volatility is is perhaps the most important parameter affecting subsurface gas generation from liquids stored in underground tanks. The volatilization (or vaporization) of a compound is dependent on its vapor pressure and concentration (relative to the surrounding media) and the temperature, pressures, and porosity of the wastes and surrounding soils. Theoretically, gases generated from liquid wastes will continue to be generated until a liquid and vapor-phase equilibrium is established (i.e., the rate of vaporization equals the rate of condensation). The greater a compound's vapor pressure, the greater will be its ability to volatalize. Compounds with very low vapor pressures (generally less than 0.1 mm Hg) tend to remain in the liquid phase.

Combustion requires a combustible waste type in addition to a source of oxygen. Typical waste types deposited in landfills include paper, wood, and flammable liquids. Typical wastes in underground tanks include flammable liquids such as solvents, waste oil, and other fuels.

Other factors that impact physical decomposition primarily result from waste management operations. Unit operations can prevent volatilization by providing maintenance of underground tanks (pressure- relief valves and leak detection systems). At landfills, operations to inhibit underground combustion center on the prevention and control of fires. In a landfill, combustion can convert wastes to by-products such as carbon dioxide, carbon monoxide, and trace toxic components. In addition, the increased temperatures from combustion may enhance chemical reaction rates and biological decomposition, and create greater driving forces for gas migration. Volatility is compound-specific, based on physical properties, temperature, and pressure. Thus, the primary gases of concern from physical decomposition include a wide range of volatile constituents, including all those listed in Table 1-2.

2.2 GAS MIGRATION

Subsurface gas migration towards facility structures or property boundaries concerns potential pathways and barriers for movement through the surrounding soils. Barriers affecting migration are influenced by hydrologic and geologic site conditions, soil properties, and unit design and operation features.

2.2.1 Natural barriers

Gas migration can be impeded or prevented by hydrologic barriers such as surface water, ground water, and saturated soils. Subsurface gases that come in contact with these conditions will tend to migrate towards the pathway of least resistance, usually through a porous soil. As an uncommon example, if a landfill or site closed as a landfill was surrounded (along all sidewalls and bottom) by water, gas migration beyond the confining barrier would not be expected. In most cases, however, ground water and saturated soils only partially surround a unit (usually along the bottom). Thus lateral or vertical migration can occur.

Gas migration can also be impeded or prevented by geologic barriers such as unfractured rock or soil with low permeability. Soil permeability is perhaps the most important natural barrier to gas migration. Permeability is a function of soil type. Clayey gravels and sand and organic clays will restrict gas flow at SWMU sites. Conversely, clean gravels and sands have high permeability, allowing subsurface gases to freely migrate. Soil permeability can be impacted by climatic conditions such as precipitation or freezing. Both tend to reduce the porosity of surface soils preventing upward gas migration.

2.2.2 Design Barriers

Landfills and sites closed as landfills may be designed with caps and liners to prevent moisture infiltration and leachate percolation to ground water. If subsurface gases are generated from these units, these same caps and liners act as barriers to gas migration. Generally, caps promote lateral gas migration since upward movement to the surface is restricted. Effective liners restrict lateral migration into the surrounding unsaturated soils. Similar to liners, slurry walls are used to border landfill units and can restrict gas movement. Caps and liners are not typically designed with underground tank units. However, these tanks are often placed into soils with clay backfill during installation, followed by paving on the surface. Thus, any escaping gases from a leaking underground tank may migrate laterally or along the least resistant pathways adjacent to the units.

Control systems for subsurface gas are designed to prevent migration into structures or beyond property boundaries. Control systems may be passive or active. Two basic types of systems are barriers and vents or extractive systems. Barriers prevent migration by providing an impermeable area between the gas source and the area to be protected. Barriers include synthetic membranes and air injection systems. Venting systems provide an easy path for the gas to vent through before migrating to areas needing protection. Vent systems include passive vent trenches and active extraction systems. The latter also include flares to burn the gases in order to control odors.

Control systems for subsurface gas are almost exclusively associated with disposal sites for municipal-type waste rather than for hazardous waste. Thus they will be rare at hazardous waste facilities and likely only present where municipal waste is codisposed with hazardous wastes or where a sanitary landfill is operated on the same site.

SECTION 3

IDENTIFYING RELEASES

3.1 APPROACH

The preceding sections have evaluated landfills, sites closed as landfills, and underground tanks in terms of the potential for subsurface migration of methane and other constituents of concern. Since few SWMU's are presently monitored for gases and since monitoring programs are difficult and often unnecessary to establish, a Preliminary Assessment (PA) is appropriate to determine if specific units will generate sufficient amounts of methane or other constituents to cause a subsurface gas release. Certain units will not generate gases, or will generate only minor amounts so that further evaluation will not be required. To make these determinations, information can be collected from construction documents, permit and inspection reports, and records of waste disposal, unit design and operation, and past documentation of accidents, spills, and releases.

As a first step, each SWMU at the facility should be identified and located by the owner or operator on a topographic base map. This would include former, existing or new SWMU's. For example, the location and aerial extent of each SWMU should be confirmed by historical records, aerial photographs, or geophysical surveys. The depth, dimensions, and capacity of underground structures, deposited wastes, and on-site buildings, should be described to assist the permit writer during the PA.

Existing construction, operation, and monitoring records can be used to determine if hazardous constituents have been managed at the SWMU. Records of waste disposal, unit design and operation, and documentation of accidents, spills, and releases should be included during review by EPA to determine if a potential exists for a subsurface gas release from the SWMU.

Waste disposal records include waste type, quantities managed, location of wastes and the date of waste disposal. This information might include waste receipts, waste composition surveys, and records of special wastes such as municipal-type refuse, bulk liquids, sludges, contaminated soils, industrial process wastes, or inert materials. For underground tanks, this information may address liquid waste compositions, quantities, and physical properties.

Unit design and operation records provide background information on site-specific construction methods. Engineering design plans, inspection records, operation logs, regulatory inspection and enforcement logs, damage or nuisance litigation, and routine monitoring such as ground-water sampling. For landfills and surface impoundments closed as landfills, these data may include to the presence and thickness of a liner, ground-water levels, waste moisture contents, type and amount of daily cover, records of subsurface fires, in-place leachate and/or gas collection systems, etc.. For underground tanks, construction and monitoring records may provide historical information on tank integrity, indicating if a leak has occurred.

Past documentation of accidents, spills, and releases can be helpful if Federal, State, or local authorities were notified. This information provides a historical perspective on problems, corrective actions, and controls initiated.

Further information may be obtained by performing a site investigation (SI), including field observations and interviews with facility owners or operators. The SI's are technical observations of SWMU's to detect evidence of a potential release. Although not extensive, the SI is conducted in the vicinity of each unit for indications of a release, including settlement, erosion, or cracking of covers, stressed or dead vegetation, contamination of surface waters, odors, elevated temperatures in control or monitoring wells or active venting of gases or smoke.

The SI's might address the condition of monitoring, containment, or control systems and any obvious structural defects in tanks, liners, etc.. Observations should be made to check overflow/alarm shut-off systems, subsurface leak detection systems, secondary containment structures (e.g., concrete pads, curbs, or dikes), and other safety triggers for early detection of potential releases. If monitoring, control, or leak detection systems are not in-place at the SWMU, SI's may be limited to primarily visual aspects and reviews of site conditions to evaluate if a release is suspected.

3.2 PRELIMINARY ASSESSMENTS

A checklist for identifying actual or potential subsurface gas releases during a Preliminary Assessment (PA) is shown in Table 3-1. The checklist is designed to allow the permit writer to review the PA data and to determine whether subsurface gas is migrating or will migrate beyond the facility boundary or into on-site or off-site structures at concentrations that are a threat to human health and the environment.

The permit writer will be concerned with two types of subsurface gas migration: (1) methane (CH_4) and (2) gases containing the other constituents of concern, listed in Tables 1-2 and 1-3. These other constituents of concern must be evaluated only if the facility owner/operator or permit writer believes they are present in amounts that may pose a threat to human health or the environment.

The PA involves a desk-top evaluation of a facility to identify a release or potential exposure from future releases. Information used by the permit writer includes the Part A and Part B permit applications. Personal knowledge of the site is important. Additional information may be available from the owner/operator or from other sources.

The PA Checklist guides the permit writer through the evaluation. The checklist is divided into five sections. The first three are

TABLE 3-1 PRELIMINARY ASSESSMENT CHECKLIST

Criteria	Response* Y	N	U	N/A
I. Unit Characteristics				
• Unit is a landfill that contains organic or volatile wastes.	___	___	___	___
• Unit is a surface impoundment or waste pile that has been closed as a landfill and covered, with organic or volatile wastes.	___	___	___	___
• Unit is an underground tank that contains volatile wastes.	___	___	___	___
If answers to all above items are No, no further evaluation is needed.				
II. Boundary Conditions				
• Unit is entirely surrounded within the property boundary by surface water, or impervious rock with no facility structures located inside the surrounding boundary or on top of unit.	___	___	___	___
• Unit has effective gas migration control system(s) protecting both on-site and off-site structures.	___	___	___	___
If either answer above is Yes, no further evaluation is needed.				
III. Quantitative Measurement of Release				
• The methane level is LEL at property boundary or 25% LEL in facility structures.	___	___	___	___
• Constituents listed in Table 1-4 measured at PEL at property boundary or in facility structures.	___	___	___	___
If answers to <u>both</u> of above are No and permit writer <u>is</u> confident of reported results, no further evaluation is needed.				
If <u>either</u> answer above is Yes, a Site Investigation should be conducted.				

Table 3-1 (Continued)

Criteria	Response* Y	N	U	N/A
IV. Other Evidence of Release				
• History of methane-related fires and explosions.	___	___	___	___
• Leak detected and confirmed in underground tank.	___	___	___	___
• Complaints on file with local/State health or fire authorities of odors seeping into basements and subsurface areas.	___	___	___	___
V. Migration Distance				
• Property boundary or structures on - or off-site less than 800 ft. at a landfill or landfill-type unit.	___	___	___	___
• Structures on - or off-site less than 300 feet from an underground tank unit.	___	___	___	___

*Y = Yes
N = No
U = Uncertain
N/A = Not applicable

used sequentially to eliminate facilities with virtually no possibility of a release or those with good monitoring data that indicate no release. These sections will eliminate many facilities from further evaluation because these facilities do not contain landfills or underground tanks. However, most landfill or underground tank sites will not be eliminated from further evaluation in the first three sections, but will be subjected to Sections IV and V as part of the PA.

Sections IV and V of the checklist help assess the majority of landfill and underground tank sites. These are sites with little or no subsurface gas monitoring data. Section IV assesses indirect evidence of a subsurface gas release and Section V is concerned with the distance from landfill units or underground tanks to the property boundary and structures.

If a site "passes" the PA Checklist, it is considered to have no current releases and the potential for exposure from future releases is small. Sites that fail the PA Checklist should be subjected to a Site Investigation to obtain monitoring data and other site-specific information for a more detailed evaluation. Pass/fail criteria are presented in Section 3.2.5.

The use of predictive models was not included in the PA Checklist. Several models of subsurface gas (primarily methane) migration have been developed. A simplified version was included in the instructions to the Open Dump Inventory. Even the simplified version requires data such as the age of the landfill, depth of fill, and soil types around the fill. This informatioin is not readily available for closed units. Thus predictive models were considered too burdensome on both the permit writer and the owner/operator at this point in the site assessment. The question of current and potential migration can be better answered by use of the PA Checklist plus a later Site Investigation involving actual monitoring. Predictive models may be applicable in a later, more sophisticated evaluation when detailed, site-specific information is available.

3.2.1 Checklist Section I

The checklist is generally self-explanatory. However, suggestions for its use and sources of information are presented in this and subsequent sections.

Section I identifies the types of units of concern for subsurface gas releases: landfills and units closed as landfills containing organic or volatile wastes, and underground tanks with volatile wastes. Examples of wastes that are organic are coal and peat processing wastes; incinerator, composting, and resource recovery residues; septic tank pumpings; wood; sewage sludges; and municipal-type solid waste. Volatile wastes are defined as those compounds that have a vapor pressure at 20°C that exceeds 0.1 mm Hg. Tables 1-2 and 1-3 may be used to identify the types of waste likely to contain constituents of concern.

Units that meet the criteria in Section I of the checklist have potentials to generate subsurface gas. Other types of units will not be evaluated unless the permit writer observes evidence of migration by other means. As an example, no further evaluation would be necessary at a demolition landfill accepting inert materials that did not in the past or does not presently accept organic waste.

Sources of information for Section I include the waste type and waste characterization information in the Part A and Part B permit applications. Little information about colocated or codisposed nonhazardous organic waste will be easily available. Contact may have to be made with the owner/operator regarding this. Both current and past operations are of interest. In addition, contact could be made with the State's solid waste permitting office, county planning office, or similar sources to identify or confirm the presence or absence of disposal areas at the sites in question.

3.2.2 Checklist Section II

Section II identifies situations where natural or manmade control systems effectively control migration of subsurface gas. Natural barriers completely surrounding the units will be almost nonexistent. Although many municipal landfills have gas migration controls, the controls often protect specific portions of the perimeter from gas movement and do not control the entire site. It is unlikely that closed sites have controls.

If a site is reported to have a control system completely around it, the permit writer must be confident that it is operating effectively. This can be shown by site monitoring data, operating manuals, and confirmed by contact with local fire and solid waste offices. Very few, if any, sites that fail Section I will pass Section II and be released from further evaluation.

3.2.3 Checklist Section III

Subsurface gas monitoring data may be available from the facility; however, that is not likely. Direct quantitative measurements can be made during the SI through the simple field sampling methods described later in this guidance. However, when any of the indicator constituents of concern is measured at or above the levels specified in Section II of the checklist, a release has occurred and the permit writer should initiate a SI as soon as possible to fully define the release and to assess the need for emergency action. See Section 4 of this manual related to emergency situations.

An owner or operator may submit monitoring data indicating no release. The permit writer must be confident that the monitoring was done properly and completely before passing a site. Note that monitoring data must be available for both methane and the indicator constituents shown in Table 1-4.

Monitoring procedures should be fully documented. Information needed is indicated later in the section describing SI field sampling methods. Some items include:

- Locations and depths of sampling
- Methods used including sketches or photos
- Instruments used
- Date and atmospheric pressure
- Analytical methods and laboratory used, if any.

Monitoring subsurface gas is a specialized field. The permit writer should review submitted data with someone experienced in the area. Sources include solid waste management offices in major cities or at State offices or consultants experienced in the topic.

3.2.4 Checklist Sections IV and V

These sections include the evaluation of indirect evidence of releases or potential exposure from future releases. Sources of information will vary widely. The owner or operator can be asked about the history of methane-related incidents, leaks from underground tanks, and odor complaints. The responses should be verified through contacts with State or local government personnel. The owners or operators should be able to provide appropriate contacts. Possible sources of information include:

- Methane-related fires or explosions
  - local fire department
  - local solid waste management office
  - local emergency response or disaster teams

- Odor complaints
  - generally same as above

- Underground tank leaks
  - EPA Regional or State inspectors or enforcement personnel
  - local fire departments or emergency response teams

The distances noted in Section V may be available on the maps submitted with Part A or Part B permit applications. However, closed units or active sanitary landfills may not be shown. Likewise all on-site and off-site structures may not be shown. The owner or operator should be contacted for the necessary information. For purposes of the checklist, the term structure should be used in the broad sense of any enclosed building that personnel enter even infrequently.

3.2.5 Checklist Evaluation

Sites will either pass the PA Checklist evaluation and not be subjected to further evaluation of subsurface gas migration or they will fail and a Site Investigation will be conducted. Sites can fail either in Section III of the PA Checklist if a release is shown or in Sections IV and V. If a site is subjected to evaluation on criteria in Sections IV and V of the checklist it should be failed and a SI conducted if either of the following occur:

- One or more Yes responses in Section IV or V
- Two or more Uncertain responses in Sections IV and V combined.

Personal knowledge of the facility will be important during the PA. Responses of the permit writer on the PA Checklist should be tempered with experience with the site. If there is any uncertainty, the U response should be made rather than the N response in Section IV and V. Examples are the distance criteria in Section V. A structure may be more than 300 ft. from an underground storage tank. However, if the surface between the tank and the structure is paved, migration to the building is possible and a U response is appropriate.

The decision criteria are strict but appropriate. Injury or death from a methane explosion can come quickly and with virtually no warning. Often there is little or no concern about subsurface gas until there is a tragic accident. The effort required for a SI is well spent if there is <u>any</u> uncertainty in order to identify releases or potential releases so that they may be controlled or prevented.

3.3 SITE INVESTIGATIONS

Site Investigations (SI's) should be conducted at sites that fail the PA Checklist criteria, either in Section III or Sections IV and V. The most important results of a SI will be the monitoring and sampling for subsurface gases in the soil and in on-site structures. Other information to be collected during a SI include soil characteristics, presence and effectiveness of any gas control systems, and the proximity and construction of buildings on - and off-site.

For simple field tests conducted during the SI, the locations of probes and timing of samples is important. Sampling locations and probe depths should be based on soil types, structure locations, vegetative stress patterns, and the waste type.

3.3.1 Monitoring or Sampling Inside Structures

To test for subsurface gases inside a facility structure, sampling conditions favorable to detecting gases are desired. Specifically, monitoring should be conducted after the building has been closed overnight or for a weekend, and when the soil surface has been wet or frozen for several days. Sampling should be performed in confined areas where gas may accumulate, such as basements, crawl spaces, near floor cracks, attics, around subsurface utility connections, and in untrapped drain lines. Gas recovery and gas control equipment need not be sampled. The results, location, date, barometric pressure and time for each sample should be recorded. It might be desirable to repeat the tests at a later date or under different climatic conditions to verify the readings, particularly if the facility is considered high priority based on structure locations and migration distances. Monitoring results should be tabulated and plotted on a map of the facility.

3.3.2 Subsurface Monitoring or Sampling

Subsurface monitoring should begin around the units identified in Section 1. Initial monitoring should be done as near the edge of the unit as possible, but not in the unit. If gases are detected, monitoring should be done further from the unit to identify general migration paths. The exact location and depth of the monitoring points should take into account any gas permeable seams, such as dry sand or gravel, alignment with an off-site structure, proximity of the waste deposit, areas where there is dead or unhealthy vegetation that might be due to gas migration, and areas where underground construction might have created a natural path for gas flow (utility lines).

In soils that are of uniform depth, subsurface gas probes or sampling points should be at least three feet below the ground surface. Where dry sand, gravel, or more gas permeable soil strata might interconnect the waste deposit and the property boundary, multiple sampling points should be used, with the uppermost three feet deep and additional ones in the deeper permeable soil layers. General techniques for installing monitoring and sampling probes are provided in Table 3-2 and Figure 3-1.

3.3.3 Methane

Simple field sampling methods for methane have been described previously and in 40 CFR Part 257.3-8(a). Methane field sampling can be performed with combustible gas meters, or by volumetric sampling and subsequent analysis by gas chromatography. A combustible gas meter will provide a reliable determination of methane concentrations. Reported experience indicates 0 to 100 percent LEL detection to be accurate with hot-wire catalytic combustion principal instruments. Since subsurface gas release determinations only require readings of methane concentrations up to LEL (5 percent methane), this single scale is sufficient. However, many users prefer instruments with the capability of determining both the 0 to 100 percent LEL and the percent methane present when the concentration exceeds 100 percent LEL (5 percent methane). Dual scale instruments are available for this application. Typically, the 0 to 100 percent gas scale uses a thermal conductivity sensor. The carbon dioxide in landfill-generated gas is reported to interfere with the thermal conductivity sensor, so the readings above 100 percent LEL, while useful, cannot be assumed to be accurate. Some of the single scale 0 to 100 percent LEL instruments can also be fitted with air dilution tubes or valves to allow readings of the percent gas when

TABLE 3-2

SUBSURFACE SAMPLING TECHNIQUES

SHALLOW (Up to 6 ft. deep)

- Select locations as described in text.
- Penetrate soil to desired depth. A steel rod 1/2 to 3/4 in. dia. and a heavy hammer are sufficient. A bar punch is better for numerous holes. It is a small, hand operated pile driver with a sliding weight on the top. Hand augers may also be used.
- Insert plastic tubing to bottom of hole. Tubing may be weighted or attached to a small diameter stick to assure that it gets to the bottom of the hole. Tubing should be perforated along bottom few inches to assure gas flow.
- Close top of hole around tubing.
- Attach meter or sampling pump and evacuate hole of air-diluted gases before recording gas concentrations or taking samples.
- When using a meter, begin with the most sensitive range (0 - 100 percent LEL for methane). If meter is pegged, change to the next least sensitive range to determine actual gas concentration.
- Tubing shall be marked, sealed, and protected if sampling will be done later.
- If at all possible, monitoring should be repeated a day or two after probe installation to verify readings.

DEEP (More Than 6 ft. deep)

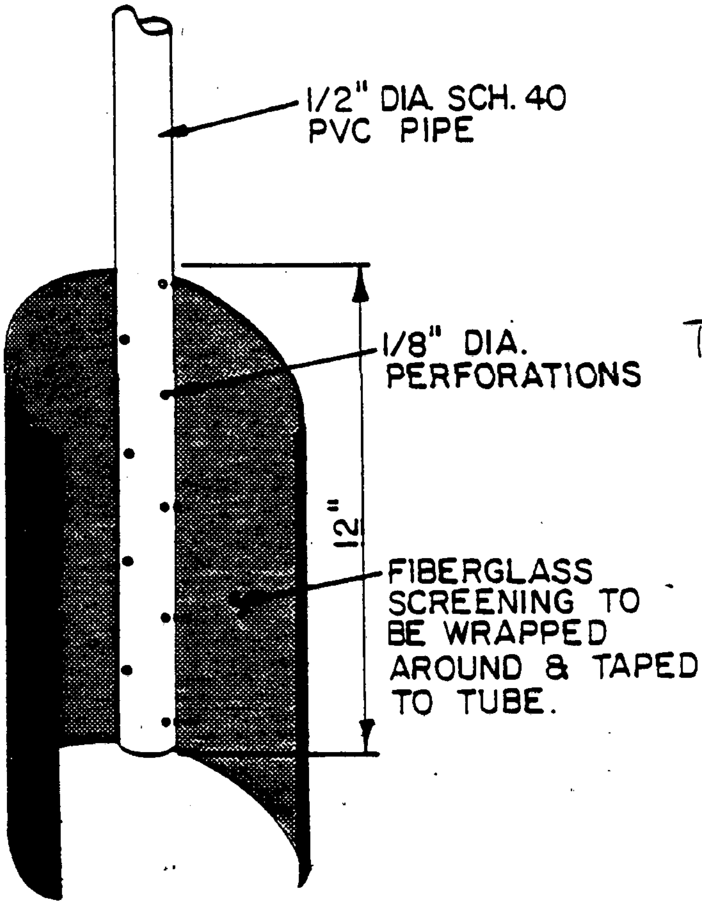
- Same general procedures as above.
- Use portable power augers or truck-mounted augers.
- For permanent monitoring points, use rigid PVC tubing and the general construction techniques shown in Figure 3-1.

CAUTION

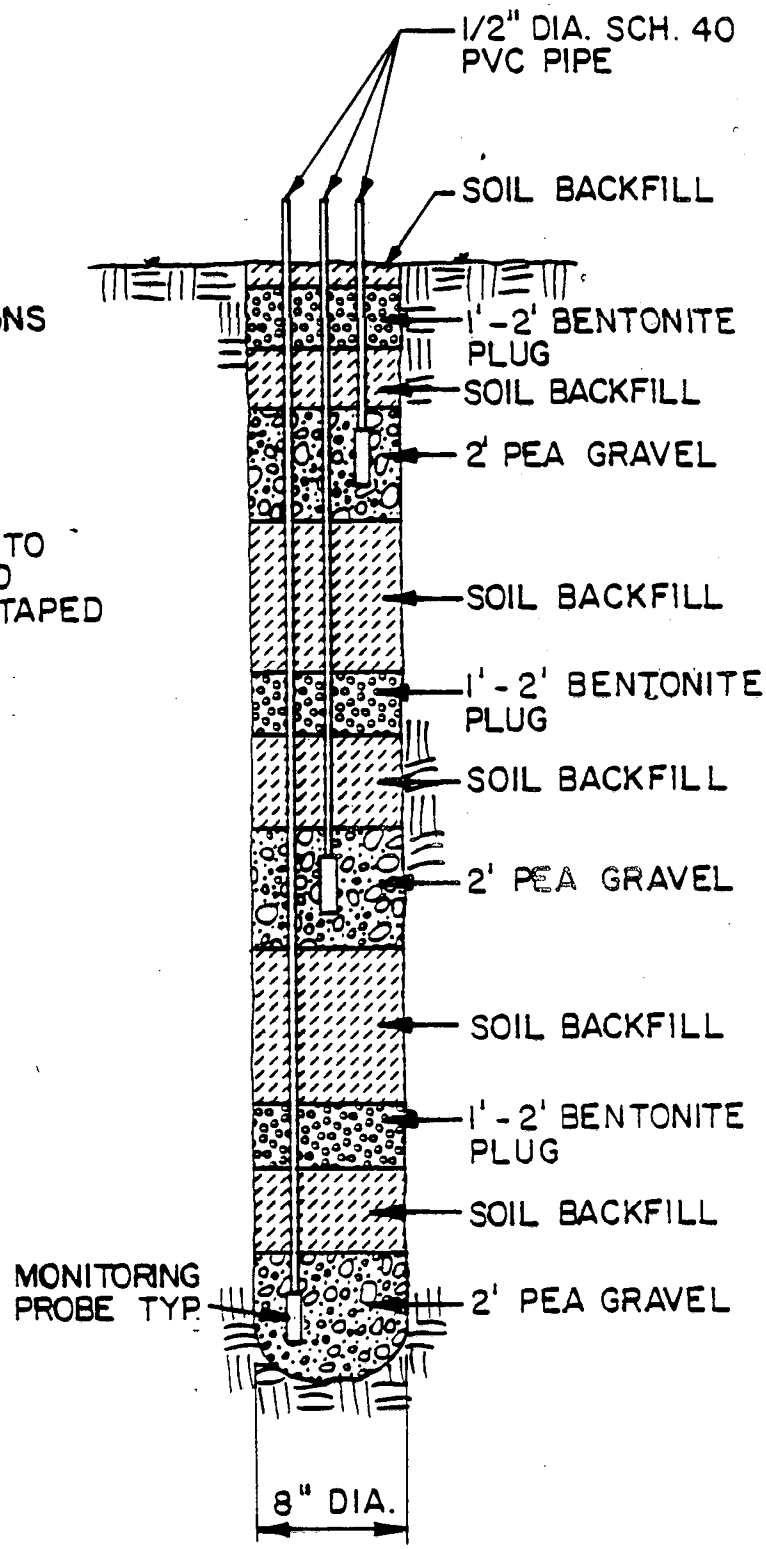
- When using hand powered equipment, stop if any unusually high resistance is met - it could be a gas pipe or an electrical cable.
- Before using powered equipment, confirm that there are no underground utilities in the locations selected.

FIGURE 3-1

TYPICAL DEEP SUBSURFACE GAS MONITORING WELLS



MONITORING PROBE DETAIL



the concentration is above the LEL. Instructions on the use and calibration of these instruments should be obtained from the manufacturer.

When sampling with a combustible gas meter, samples should be withdrawn slowly with the hand bulb until a high or constant reading is obtained. For small diameter holes in tight soils, a spike reading may be obtained initially and the concentration will then drop to a low value. This is caused by exhausting the gas in the hole. The spike reading should be recorded and checked by allowing the gas to return for a few minutes and taking another reading. The location or probe number, the time and date, and the results should be recorded.

For volumetric sampling, subsurface gas can be collected in an evacuated flask or bottle with a vacuum pump. The volume of air in probes or gas lines should be purged prior to obtaining the sample. Generally, a 150 ml sample is appropriate. This sample is then sent to the laboratory for analysis of methane by volume.

3.3.4 Other Indicator Constituents

The other indicator constituents listed in Table 1-4 can be measured by several methods, all of which require more extensive sampling procedures, equipment, and instrumentation than combustible gas meters for methane. There are two basic methods for collection of subsurface gas samples. In one, a gas sample is obtained in a flask, bottle, bag, or other suitable container; in the other, gases or compounds are removed from the air and concentrated by passage through an absorbing or adsorbing medium.

The first method involves the collection of volumetric samples, usually a liter or so depending on concentration and desired detection limits. This type of sampling is convenient and easily performed in the field. Evacuated stainless steel cylinders are frequently used for sample collection. However, sample loss or decay can occur with various containers (such as plastic bags) and prompt laboratory analysis is required. To detect the indicator constituents at levels fitting the definition of a release, the volumetric sample collection method is acceptable, coupled with the appropriate analytical methods. This type of sampling is less reliable when compound concentrations fluctuate with time, or are low, or when the gas sample is a complex mixture of many compounds.

Because low concentrations of a wide variety of volatile organics are frequently observed in subsurface gases, many compounds can be more efficiently collected and simultaneously analyzed by continuous sampling and collection onto a solid adsorbent. The solid adsorbent concentration method uses a vacuum pump and adsorbent traps to collect and concentrate volatile organics. Specific adsorbents (such as activated charcoal or silica gel) can be selected according to compound volatility and the type of organics sampled (such as chlorinated hydrocarbons or pesticides).

Flow rates through the adsorbent traps and sample volumes must be selected prior to sampling, and then carefully measured during sampling with calibrated meters. After sampling is completed, the traps are sealed and shipped to a laboratory for analysis.

Several analytical methods are available for both volumetric and concentrated trap samples. For quality control requirements, EPA has approved Method 1624 for volatile organics in 40 CFR Part 136. This method is amenable to the indicator constituents of concern.

Portable detection meters are not recommended for monitoring for constituents other than methane. These instruments must be recalibrated for each different constituent.

3.3.5 Factors Not Related to Monitoring

During a SI no release or even no migrating gas at all may be found. However, there is the possibility of future releases resulting in exposure of the public. SI inspections should include factors related to the potential for releases and migration. These factors are generally related to site location and soils, subsurface gas control systems, and construction of on - and off-site buildings.

Site location, soils, and surface and ground water influence the potential for subsurface gas migration. Tight, uniform soils such as clays at least to the depth of the unit are good barriers.

Sand and gravel lenses below a less permeable cover are excellent conduits for gas migration. However, sandy soil will likely encourage venting of gas to the atmosphere with little chance of horizontal migration. Observation of soil types at the site is important. Other soil information from the Part B permit application will also be helpful in assessing future migration potential.

Water is a barrier to gas migration. Subsurface gas does not penetrate ground water and surface water is usually a good barrier. An exception is a pearched body of surface water with unsaturated soil below it. Thus if there is a lake or perennial stream between the unit and any structure, future migration and exposure is unlikely. High ground water restricts migration to the unsaturated zone. This focuses interest in soils to only that zone. High water tables also allow for the use of effective but relatively inexpensive trenches as gas control devices.

Some sites may have gas migration controls. If properly designed and located, they can greatly reduce the possibility of future releases, even if the controls do not completely surround the unit. Control systems are usually constructed to protect existing structures. If future building is possible, a system may have to be expanded.

Control systems may be either passive or active. Passive systems require no energy and little maintenance. They are vents to the atmosphere or barriers. Assuming proper design and construction, the only passive system not considered effective is a series of vent wells. Active systems withdraw gas through wells or develop pressure curtains by injecting air into the soil. Assessment of effectiveness should be done by personnel experienced with gas migration control. Control systems are described more fully in Section 5.

Exposure to subsurface gas may be affected by the type of construction used for buildings on or off the site. SI inspections should at least determine the general construction techniques used. Subsurface gas accumulates in basements, crawl spaces, and other confined areas where there is easy passage for the gas from the soil into the building. Buildings built with slab-on-grade or with well ventilated crawl spaces are less likely to have gas accumulations than other types; however, cracks in floors and gaps around utility penetrations can provide good conduits.

3.3.6 Evaluation

SI monitoring data may identify a release or even an emergency situation (see Section 4). This will likely lead to permit conditions to correct the situation or to more detailed studies to prove that risk of future exposure is low.

Monitoring data may indicate that no indicator constituents are present or they are at concentrations less than the criteria for a release. In these situations, future releases are possible. SI investigations should assess the likelihood of future releases and potential exposures of the public. Provisions of RCRA regulations should be kept in mind related to reopening permits and the 10-year life of permits. If a site poses a threat of future release and exposure of the public before regulatory corrections can be applied, the site should be failed and more detailed Remedial Investigations conducted.

SECTION 4

REMEDIAL INVESTIGATIONS

4.1 EMERGENCY SITUATIONS

4.1.1 Criteria

An emergency situation with regard to subsurface gas exists when gas has accumulated in a structure to the degree that an imminent hazard to human health is present. For methane, an emergency situation exists when the gas is found at concentrations equal to or above its lower explosive limit (LEL). The LEL for methane is five percent in air. Any concentration of methane between 5 and 15 percent is explosive. Above 15 percent in air, the methane is flammable. Both situations should be considered as emergencies. The criteria for a methane-related emergency situation should be applied to structures both on and off-site. Likewise both occupied and non-occupied structures should be included.

Emergency situations may also exist due to the presence of other subsurface gases. For subsurface gas constituents of concern other than methane, an emergency situation exists if:

- o a constituent of concern is present in a structure at concentrations greater than its PEL (or other exposure limit as discussed in Section 2), and
- o the structure is occupied routinely (five or more days per week) by the same personnel for eight hours or more each day of occupancy.

This definition includes structures both on-site and off-site. Obviously, dwellings on-site and off-site are included. Other on-site structures that would be included are offices, scale houses, laboratories, maintenance garages, and other buildings with essentially continuous occupancy during an eight hour work shift. Buildings such as locker facilities, lunch rooms, and break areas that are only occupied for short periods are not included.

4.1.2 Identification

Potential and actual emergency situations can be identified through reviews of historical information and gas monitoring data. A potential emergency situation exists if there have been any reported explosions or fires (inside or outside of a structure) likely caused by subsurface methane. Also illnesses or deaths verified as related to exposure to gases within a building on- or off-site would indicate a potential emergency situation. Knowledge of the above will be extremely rare. Thus identification of actual emergency situations will rely almost entirely on monitoring data.

Historical monitoring data for subsurface gas within occupied buildings may be available, but is also unlikely. Probably only sites with a history of subsurface gas migration will have monitored inside buildings.

The possibility of an emergency situation due to subsurface gas is extremely low. Unless there is strong evidence, other than monitoring data, site visits only to monitor for subsurface gas are not warranted. Evidence to trigger a visit to monitor for subsurface gas emergency situations include:

- Municipal-type refuse is or was disposed in a landfill within the property boundary or

- An underground tank containing constituents of concern is known to be leaking.

Emergency situations will likely be identified only through monitoring by EPA or State regulatory personnel. This monitoring shall be done using the instruments identified in Section 3. Monitoring should be done in areas within structures where subsurface gas is most likely to enter and accumulate. These areas include basements, crawl spaces, and other enclosed areas such as storage rooms, closets and other areas with no windows. Gas concentrations should be checked near cracks or joints in foundations or floors and around pipes and other utilities that enter the building through a foundation wall or through the floor

Atmospheric pressure can influence the migration of subsurface gas into structures. When monitoring is being done, the barometric pressure should be recorded. The best time to sample is when the pressure is low. If possible, schedule visits for days with low pressure. If that is not possible and gas concentrations are just below the criteria for an emergency situation, schedule a return visit for a time of lower atmospheric pressure.

Off-site buildings probably cannot be monitored for subsurface gas. Permission may be obtained to monitor in buildings owned by the facility owner and possibly publically-owned buildings near the site. Monitoring inside privately-owned buildings should not be attempted unless there is a great likelihood of an emergency situation. If occupied off-site buildings are extremely close to the property boundary (less than 100 ft) and subsurface gas at the boundary is above the LEL, contact with local fire or health officials should be made and interior monitoring coordinated through them.

4.1.3 Fast-Track Corrective Actions

If monitoring data indicate an emergency situation related to subsurface gas, steps should be taken promptly to reduce the hazard whether it is related to human health or to the explosive potential of methane. A checklist of steps recommended in case of a gas emergency is shown in Table 4-1. The steps should be completed generally in the order shown; however, variations may be appropriate due to site-specific circumstances.

Corrective actions for subsurface gas releases are highly site-specific. In general, they involve either the venting of gas to the atmosphere where it is diluted or incinerated, or the pre-

TABLE 4-1

Actions to Take in Gas Emergency Situations in Buildings

1. Evacuate the building.
2. Advise fire department.
3. Ventilate by opening windows and doors.
4. If methane is present shut off utilities - gas, electricity, telephone.
5. Monitor to identify source if possible. Source could be leaking natural gas appliance or supply system. Contact local gas utility and fire department for monitoring and sampling assistance.
6. Take samples and have analyzed to identify source.
7. Control source, repair leak, etc., if source is not subsurface gas. Continue to monitor until safe levels return.
8. If source is subsurface gas, call in experienced and qualified experts to locate sources and develop corrective actions.

vention of migration through the use of barriers. Specific corrective actions should be identified by experts at the site. Some common actions are presented in Section 5.

4.2 ROUTINE SITUATIONS

Routine situations are those that are not emergencies but which are indefinite as to the potential for future releases and the resultant public exposure and health impacts. Either regulatory agencies or owners and operators may decide that more detailed data collection and analyses are appropriate. These efforts could be used to support or refute decisions related to permit conditions or the denial of a permit. Efforts related to such decisions will be referred to as Remedial Investigations (RIs).

Owners and operators may want to conduct an RI to show that even though a subsurface gas release has occurred, exposure to the public is unlikely and thus the potential risk to human health and the environment is not substantial. Similarly they may wish to propose a corrective action that is different from that required by the EPA or State. This latter situation is similar to a request for an Alternate Concentration Limit for ground-water protection.

Regulatory agencies may wish to initiate an RI to defend decisions imposing permit conditions even though no release of subsurface gas was detected during an SI. Such an RI would be focused on establishing that a substantial potential risk exists of exposure to subsurface gas if a release occurs in the future.

Two general approaches are available for the conduct and evaluation of an RI related to an actual or potential subsurface gas release. One approach is the use of predictive models for subsurface gas migration coupled with site-specific information concerning the potentially exposed population. The other approach is the use of an independent consultant experienced in control of subsurface gas migration. This approach might be considered a form of arbitration and both the regulators and the regulated organization should agree to honor the conclusion of the consultant. The consultant firm may use predictive models, however, it may also use more extensive monitoring and sampling than was done in the SI and make more thorough soils analyses and evaluation of other factors such as the abilities of buildings to prevent the intrusion of subsurface gas.

4.2.1 Predictive Models

Models have been developed to predict the migration of subsurface gas. Essentially all of them have been used to predict migration of landfill gas from open dumps and sanitary landfills where municipal refuse has been disposed. They are also applicable to the assessment of migration control system effectiveness.

A generalized model was developed for use in the Open Dump Inventory Manual and was presented in Chapter 2(a) of that manual. It was developed to predict the distance to which landfill gas would likely migrate from an open dump. Its data requirements and degree of accuracy are appropriate to landfill or landfill-type sites subjected to an RI. The model was not designed for application to a leaking tank situation, and its use for underground tanks is discouraged.

The model yields a subsurface gas migration contour map. It predicts the distance that gas will migrate from each unit based on the unit's age, depth, soil characteristics, and other factros. These distances for two concentrations of methane (LEL or 5 percent methane and 25 percent of LEL or 1.25 percent methane) can be plotted on a facility map. The resulting contours enclose areas where methane could be expected at these concentrations. If on-site structures are within the 1.25 percent methane contour or the 5 percent contour extends beyond the property boundary, a release of subsurface gas as defined in Section 1 is possible. In such situations continued monitoring and/or corrective measures should be implemented.

4.2.1.1 Data Requirements

Data requirements for use of a predictive model are likely more extensive than will be found in Part A and Part B permit applications and information collected during an SI. This is especially true of sanitary landfills and other nonhazardous disposal units located at the facility. Information requirements are listed below:

- Map of the facility showing all landfill units or units closed as landfills that contain organic or potentially volatile wastes. The map should include land use at least 1/4 mile outside the property boundaries and all structures within that area including those on-site. A sample map is shown in the example explained later.

- Information about the degree to which the surface between the landfill units and structures is impervious to gas (see example)

- For each of the above units the following is needed
  - areal extent of each unit
  - topography including elevation contours at least 1/4 mile beyond property boundaries
  - average elevation of the bottom of solid waste in each unit
  - years in which solid waste was first put into each unit
  - average elevation of a gas impermeable barrier below the solid waste (usually ground water or bedrock).
  - information on soils surrounding each unit at least to the depth of the bottom of the solid waste (descriptive soil names and classifications are included in the example).

Accurate information on subsurface conditions will be the most difficult to obtain. Surface features can be observed directly and maps are usually available including those used in Part A and Part B permit applications. The age of each unit may be a matter of record; however, for older units, knowledge of local government personnel should confirm owners' statements. The depth of fill can be estimated by comparing contour maps of the area, before and after filling. Depth to ground water or bedrock may be available from on-site or nearby water wells including ground-water monitoring wells. Soils classifications may be available from boring logs of ground-water monitoring wells. However they may describe the soils only on two sides of the site. Other boring logs may be available from local water well or construction drilling firms or local offices of the Soil Conservation Service In some instances, soil boring may have to be made.

4.2.1.2 Example Application

The predictive model is best explained through the use of an example situation at a hypothetical landfill. The example and the migration model and associated graphs were taken from the Open Dump Inventory Manual. The example landfill is shown in Figure 4-1. Both a plan view and two cross sections of the landfill are shown. They include most of the physical data needed for the model.

Other information includes the age of the landfill since it first received waste and soils information. In Figure 4-1, soils are

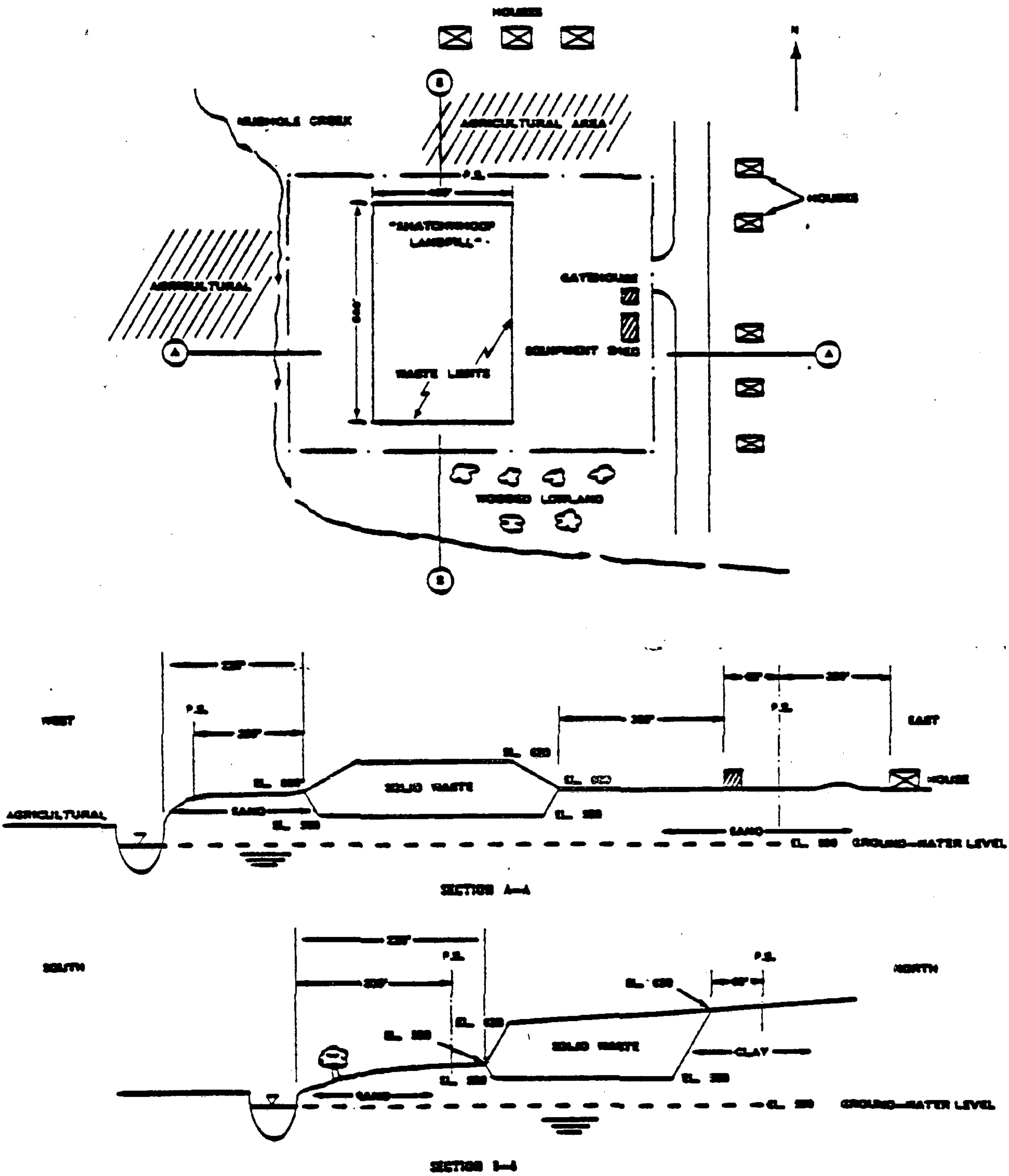


Figure 4-1

Example Landfill

shown as either sand or clay and are assumed to be uniform from the surface to the ground-water level. Site-specific soil data should be available. Soils may be described by names or via a classification system. A common system is the USCS Classification. Soil names, USCS Classification, and related graph use in the model are shown below.

Soil Name	USCS Classification	Graph Use
Clean (no fines) gravels and sands	GW, GP, SW, SP	Sand
Silty gravels and sands, silt, silty and sandy loan, organic silts	GW, SM, ML, OL, MH	Interpolate
Clayey gravels and sands, lean, fat and organic clays	GC, SC, CL, CH, OH	Clay

The model includes three basic steps. The first is the estimation of migration distances related to the landfill's age and type of soil being evaluated. The next two steps apply correction factors related to the depth of the landfill and to the degree to which surface venting is likely.

Figure 4-2 is the graph for the uncorrected migration distance. To use the graph the age of the landfill and the soil type must be known. Enter the graph at the site's age. Continue up to the curve describing the soil type and concentration of interest. Contours (migration distances) should be drawn for both 5 percent and 1.25 percent methane. If the soil type is between clay and sand, interpolate between the curves. If in doubt about soil types use the sand curves as the worst case (greatest migration distance). Read the uncorrected migration distances (5 percent and 1.25 percent) on the vertical axis. For the example landfill in Figure 4-1, the uncorrected 5 percent methane migration distances for a 10-year old landfill would be (Figure 4-2):

Section A-A: East side, 10 years, sand = 165'
West side, 10 years, sand = 165'

Section B-B: South side, 10 years, sand = 165'
North side, 10 years, clay = 130'

The corresponding uncorrected distances for the 1.25 percent methane migration would be:

Section A-A: East side, 10 years, sand = 255'
West side, 10 years, sand = 255'

Section B-B: South side, 10 years, sand = 255'
North side, 10 years, clay = 200'

The next step is the selection of a correction factor related to the depth of the landfill. The deeper the waste, the greater is the potential migration distnce. A graph of depth correction factors is shown in Figure 4-3. Enter Figure 4-3 with the unit's age along the horizontal axis. Move upward to the appropriate depth curve. The correction factor is found on the vertical axis and ranges from - 0.5 to + 2.2. Note that the curve for a land-

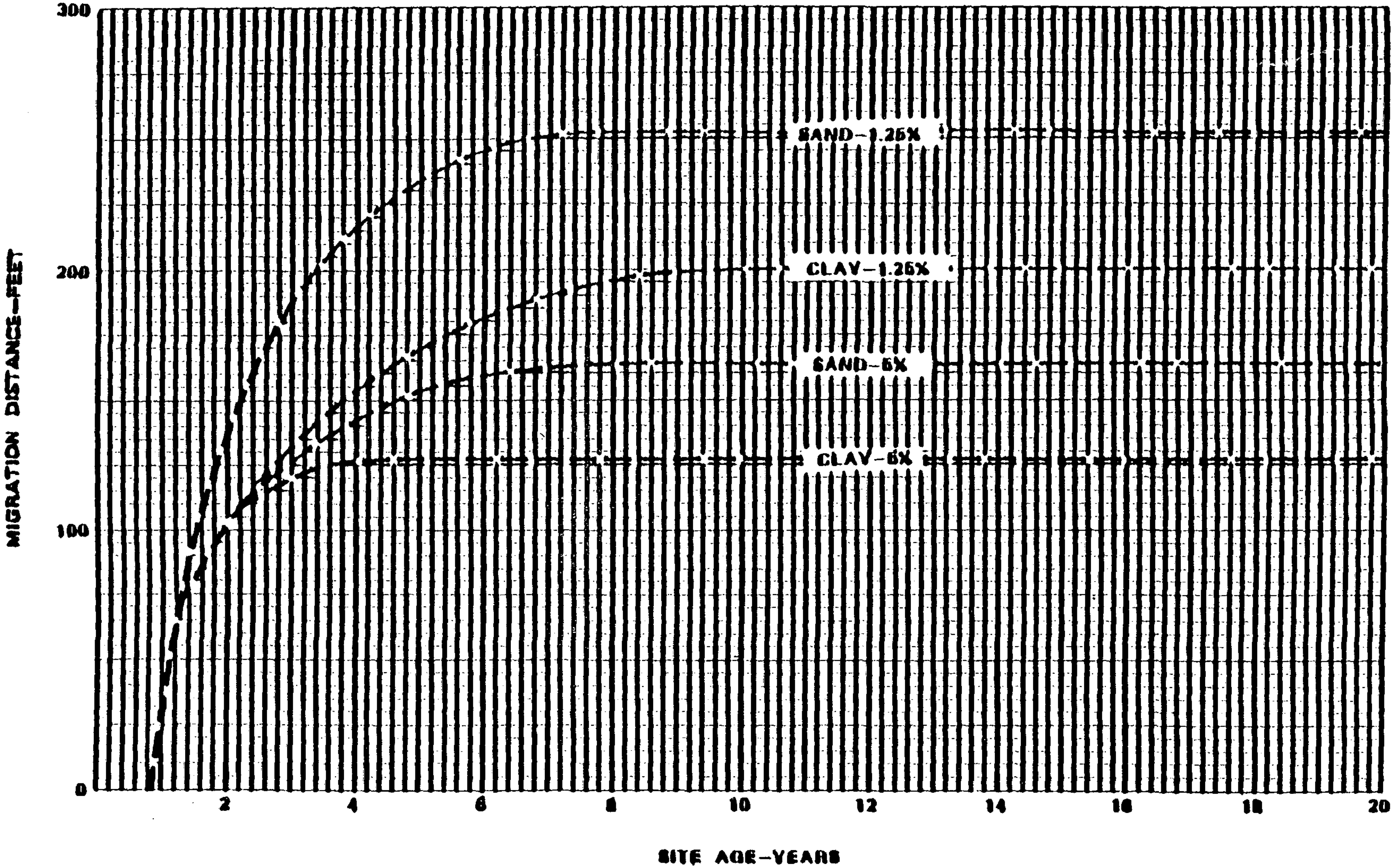


Figure 4-2

Uncorrected Methane Migration Distance

fill 25 ft deep is a straight line and yields a correction factor of 1.0. For units of different depths, interpolate between the curves, The depth corrective multipliers for the example site would be:

Section A-A: East side, 10 years, 20' deep = 1.0
West side, 10 years, 20' deep = 1.0

Section B-B: South side, 10 years, 10' deep = 0.95
North side, 10 years, 50' deep = 1.4

The corrective factors for the surrounding soil venting conditions are next obtained using the graph in Figure 4-4. This graph is based on the assumption that the surrounding surficial soil is impervious 100 percent of the time. Thus the value read from the graph must be adjusted, based on the percentage of time the surrounding surficial soil is saturated or frozen and the percentage of land along the path of gas migration from which gas venting to the atmosphere is blocked all year (asphalt or concrete roads or parking lots, shallow perched ground water, surface water bodies not interconnected to ground water). The totally impervious corrective factors on the vertical axis of Figure 4-4 are only used when the landfill is <u>entirely</u> surrounded at all times by these conditions. An adjusted corrective factor is obtained by entering the chart with site age and obtaining the totally impervious corrective factor for the appropriate depth and soil type and then entering this value in the following equation:

Adjusted corrective factor = [(Impervious corrective factor from Figure 4-4) - 1] x (% of impervious time or area] + 1

If both time and area adjustments are necessary, the percentages are additive. Estimates to the nearest 20 percent are sufficient.

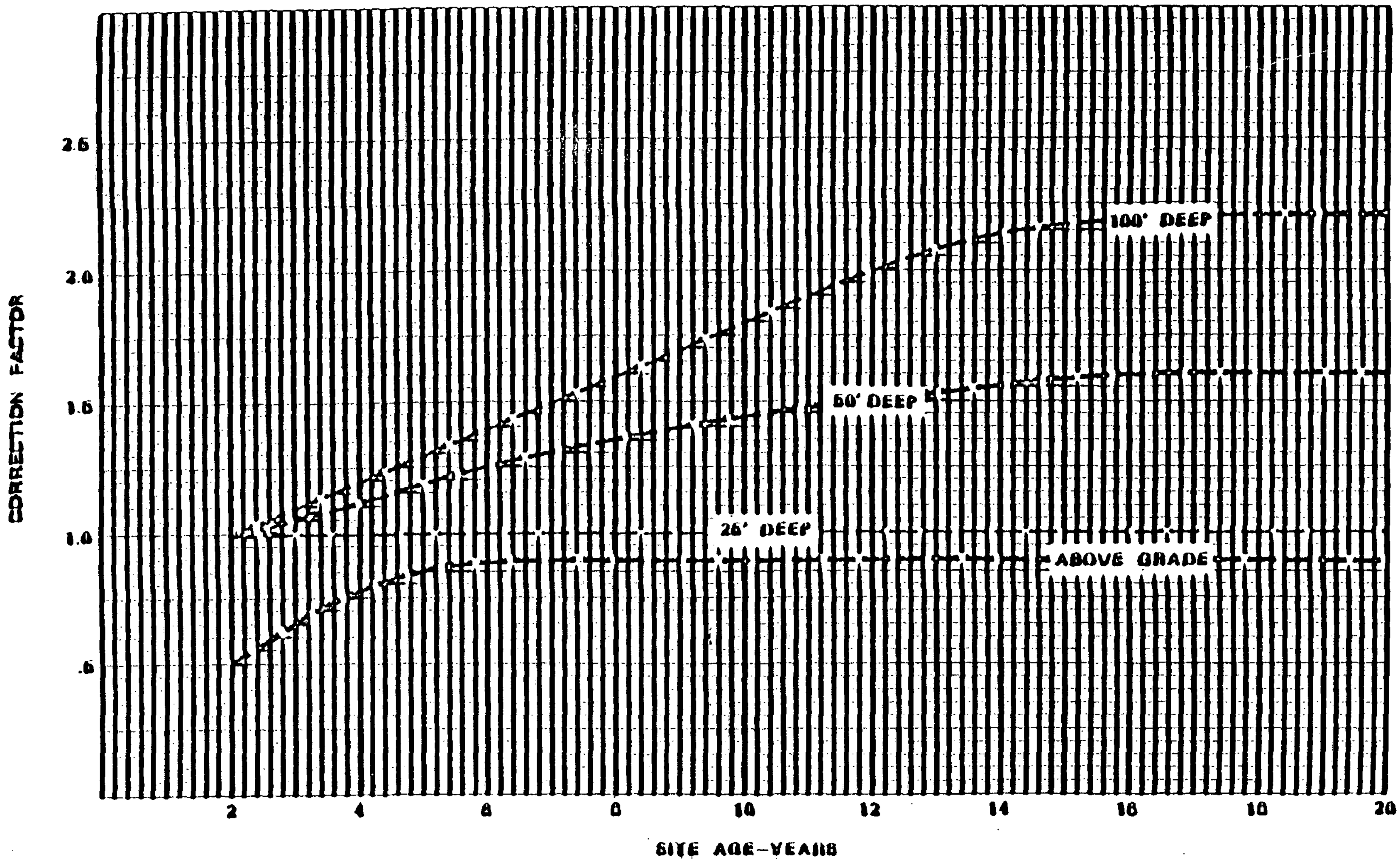


Figure 4-3

Correction Factors for Landfill Depth Below Grade

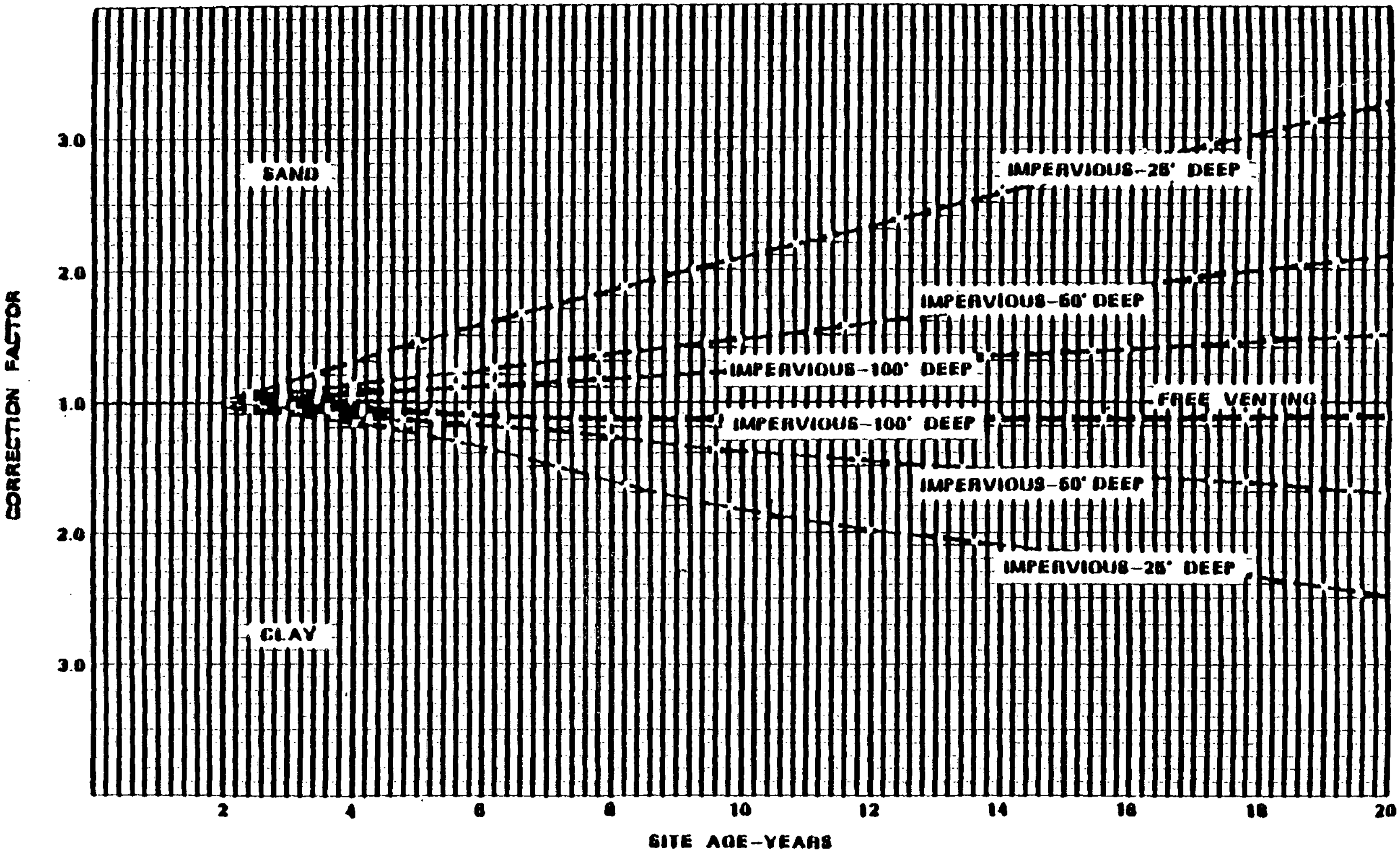


Figure 4-4

Correction Factors for Soil Surface Venting Condition Around Landfill

When free venting conditons are prevalent most of the year, simply use 1.0 (no correction). For depths less than 25 feet deep, use the 25 foot value. For the example site, the adjusted corrective factors for frozen or wet soil conditions 50 percent of the year are:

Section A-A:	East side (ignore narrow road, sand, 20' deep, 10 years old)	= (2.1-1) (.50) +1 = 1.55
	West side (sand, 20' deep, 10 years old)	= (2.1-1) (.50) +1 = 1.55
Section B-B:	South side (sand, 10' deep, 10 years old)	= (2.1-1) (.50) +1 = 1.55
	North side (clay, 50' deep, 10 years old)	= (1.4-1) (.50) +1 = 1.2

For ease of calculation, the above data are entered into a table similar to Table 4-2. Table 4-2 includes the data from the example problem. The corrected distances of probable gas migration resulting in 5 and 1.25 percent concentrations in each direction from the landfill are obtained by multiplying across the table for each side of the landfill. These values can then be plotted on the scale plan as contours of the 5 and 1.25 percent methane concentrations or simply compared to the distnces from the waste deposit to structures of concern.

The corrected distances from Table 4-2 are plotted on the map in Figure 4-5 and the resulting contours sketched. Note that surface water along the western and southern boundaries are barriers to gas migration and override the distances in Table 4-2.

Landfill Side	Methane Concentration	Uncorrected Distance		Correction for Depth		Correction for Venting		Corrected Distance
E	5%	165'	X	1.0	X	1.55	=	256'
	1.25%	255'	X	1.0	X	1.55	=	395'
W	5%	165'	X	1.0	X	1.55	=	256' * (225' max.)
	1.25%	255'	X	1.0	X	1.55	=	395' * (225' max.)
S	5%	165'	X	0.95	X	1.55	=	243' * (225' max.)
	1.25%	255'	X	0.95	X	1.55	=	375' * (225' max.)
N	5%	130'	X	1.4	X	1.2	=	218'
	1.25%	200'	X	1.4	X	1.2	=	336'

* When these distances are plotted on the landfill sketch, they exceed the distance to the creek, which acts as a barrier to the gas migration, Thus the distance to the creek is the maximum migration distance.

Table 4-2

Methane Migration Distance Tabulating Form

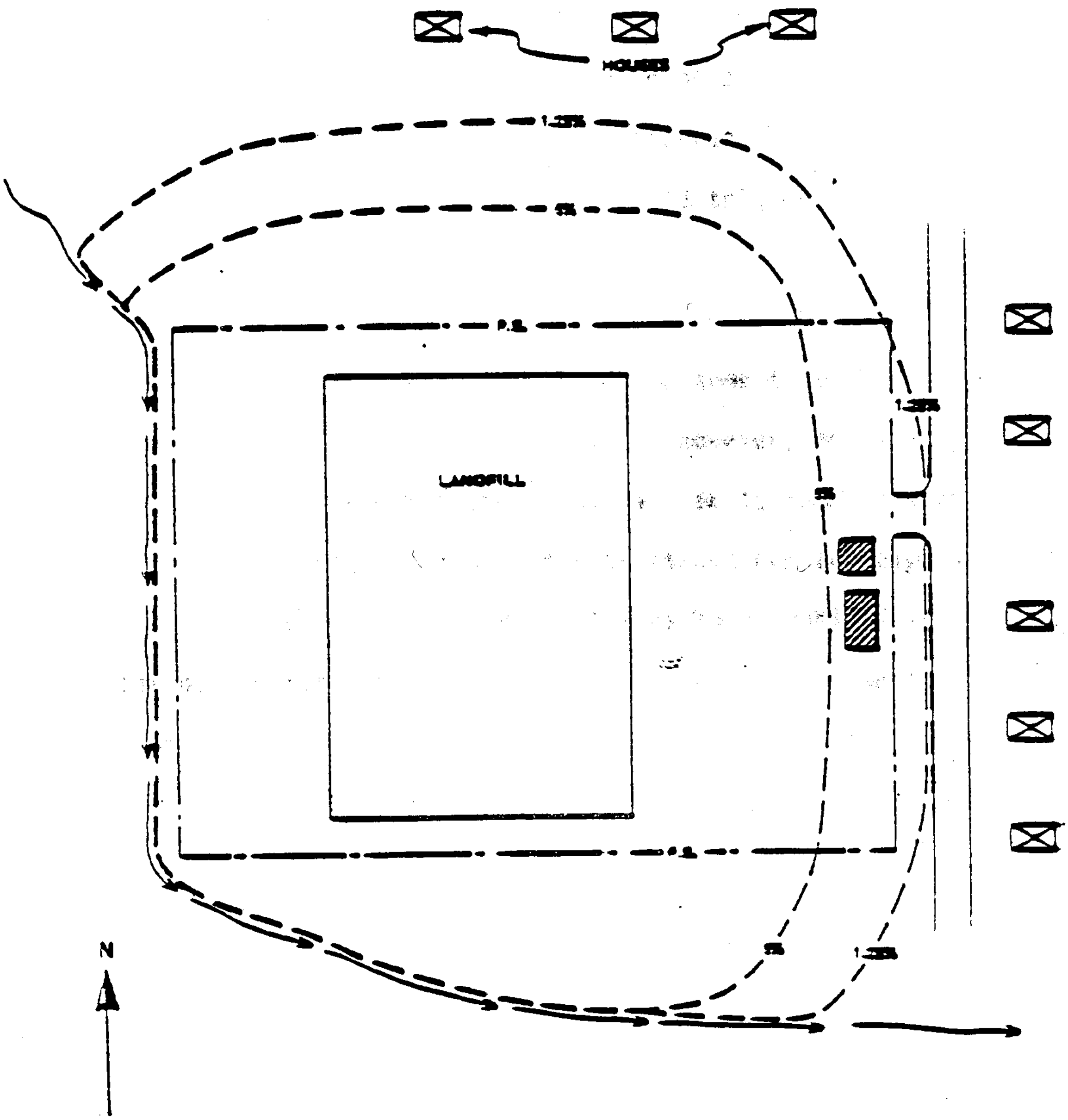


Figure 4-5

Example Landfill Methane Contours

The contour for 5 percent methane extends beyond the property boundary. A release of subsurface gas is possible even if it has not yet occurred. The 1.25 percent methane contour encloses on-site buildings but does not reach off-site structures. Thus there is a possibility of gas accumulation in on-site structures. Both contours indicate that a release of subsurface gas (as defined in Section 1) is possible. This should trigger concern for potential risk to human health.

A situation shown in Figure 4-5 should lead to some type of corrective action as described in Section 5. However, the owner or operator may want to demonstrate that the risk to human health is not substantial. The fact that off-site structures are beyond both the 5 and 1.25 percent contours indicates that problems in these buildings are not likely. On-site buidlings are close to the 5 percent contour. Factors such as type of construction, quality of sealing cracks in floors, or a gas monitoring program may be used to demonstrate that the risk is not substantial or that any potential problem will be identified before damage occurs. Thus site-specific factors may be used to confirm or refute the apparent results of the predictive model. Essentially, any site can be made safe from releases of subsurface gases. Monitoring programs, construction techniques, and gas control features can be used singly or in combination as warranted. The corrective actions that will provide advanced warning or will prevent future releases are described in Section 5.

4.2.2 Use of Experts

The predictive model may yield ambiguous results or either the EPA or the owner may know of factors not considered in the model that either raise or lower the potential for a release and for a substantial risk to human health. In such situations, experts in the area of subsurface gas generation and control should be used. Experts may also be used in lieu of the predictive model. Experts may be used by either the regulatory agency or the owner, or both. If possible, an agreement to abide by the expert's findings should be developed. If not, the assessment of the expert's findings by the regulators will usually be binding on the owner.

Experts in subsurface gas generation and control are relatively rare. Few are employed by the EPA or States and only a few major disposal firms will have experts on staff. Most gas experts are employed by a small number of environmental consulting firms or by natural gas utilities; however, the latter are less familiar with gases generated at waste disposal sites and their control. Identification of qualified consulting firms can be made by contacting the Governmental Refuse Collection and Disposal Association (GRCDA). GRCDA is located in Silver Spring, MD, and the telephone number is (301) 585-2898.

Gas experts can conduct detailed subsurface exploration and monitoring for the presence of gas. Information obtained through this field work can verify the extent of a landfill (both areal and vertical extent), identify soil and other conditions specific to the site that will encourage or impede migration, and identify gas concentrations at various depth and in directions related to occupied structures. Predictive models more sophisticated than the one described above may be used or the expert may use past experience coupled with site conditions to assess the presence or potential for a release.

Conditions that would reduce the consequences of a release should also be identified. These include the design and quality of construction of buildings. These impact on the likelihood that gas would enter a building if it was present in the adjacent soil. Experts can also recommend systems that will provide adequate protection. These may include relatively simple and inexpensive monitoring systems. As appropriate, venting or barrier systems for gas migration control can be identified. The experts used should also be experienced in both the design and operation of control systems. Protective systems may be necessary as part of permit conditions and should be designed by experienced experts and the designs be reviewed by equally qualified personnel. This review is particularly important for designs submitted by an owner.

SECTION 5

CORRECTIVE MEASURES

5.1 MONITORING PROGRAMS

After the PA/SI is complete, the owner/operator may be required to establish a gas monitoring program for the site. A monitoring program consists of the design of sampling probe types and site locations, well construction and probe installation, development of a written protocol for field sampling procedures, maintenance of the monitoring wells, data interpretation, and reporting requirements. For purposes of this guidance, a general protocol for subsurface gas field monitoring is described below. This protocol addresses field data forms, equipment, monitoring and sampling procedures, and record keeping for methane and the indicator constituents of concern.

5.1.1 Methane

5.1.1.1 General

An example data form for methane field monitoring is shown in Table 5-1. Data requirements specified include:

- General background data. These include date and time, monitoring personnel, barometric pressure and atmospheric temperatures, general weather conditions, and the types of instruments used.
- Ground-water data. Most monitoring probes are expected to be dry since they will be installed above the water table. However, precipitation or a rising ground-water

Date: ____________

Time: ____________ a.m. p.m.

Monitoring Personnel: ____________

Barometric Pressure Reading: ________ in. Hg ________ in. H_2O

Atmospheric Temperature: ________ °F ________ °C

Instruments Used:

- Water Level: ____________
- Probe Pressure: ____________
- Methane: ____________
- Barometric Pressure: ____________
- Atmospheric Temperature: ____________

General Weather Conditions: ____________

Well No.	Ground Water	Probe No.	Probe Pressure (in. H_2O)		Methane		Notes
			Gage	Absolute	% LEL	% Gas	
1	☐ Dry	A					
	☐ Wet	B					
		C					
2	☐ Dry	A					
	☐ Wet	B					
		C					
3	☐ Dry	A					
	☐ Wet	B					
		C					

Table 5-1

Field Data Form for Subsurface Gas Monitoring table can cause soil saturation and probe clogging. The condition of the probe should be marked as either wet or dry.

- Probe pressure. The pressure or vacuum is read from a pressure gauge. The reading then can be corrected to "absolute" pressure in conjunction with barometric pressure and temperature. Pressure is usually reported as in. of H_2O and ranges from very slightly negative to about 5 in. H_2O positive.
- Methane content. Through the use of a combustible gas meter, methane content of the subsurface gas can be measured in terms of percent of LEL or percent volume in air.

Completion of the data form should be routine. The date and time of sampling should be consistent. That is, if field monitoring is performed at weekly intervals, use the same day of the week. For monthly intervals, field monitoring should be performed on about the same day of the month. Similarly, field monitoring should be performed consistently at the same time of day, preferably in early afternoon when subsurface pressures are most likely to be positive.

For the barometric pressure reading, a sturdy field barometer should be used. The current direction of movement (i.e., rising, falling, or steady) should be recorded. For each monitoring day, a phone call should be placed to the National Weather Service to obtain a current reading as a check of the field barometer's accuracy. The barometric pressure reading obtained in the field is recorded on the data form in inches of Hg. If desired, it can be converted to inches of water by multiplying by 13.4. The general weather conditions (i.e., wind conditions, snow or rain, cloud cover, etc.) and instruments used should also be noted on the form.

5.1.1.2 Equipment

The following equipment and other materials should be taken into the field for each subsurface gas or facility structure monitoring round: watch, thermometer (°F or °C), barometer (inches Hg), looseleaf binder notebook, blank data forms, copy of protocol, clipboard and pen, pressure measuring devices, and combustible gas meter. The gauges used are differential pressure gauges with a 0 to 0.5 inch range or a 0 to 5 inch range. Other pressure reading accessories might include spare tubing, a mounting board for leveling, and a peristaltic hand pump.

The combustible gas meter should be calibrated for methane, with percent LEL and percent gas ranges. Other accessories might include spare batteries, spare aspirator, water trap, extra tubing, spare filaments and cotton filters, and calibration gas.

5.1.1.3 Probe pressure

The purpose of recording probe pressure is to determine whether subsurface gases are at a higher or lower pressure than the atmosphere. Often, subsurface pressures lag behind changes in atmospheric pressure, particularly for deep probes, and/or probes that are separated from the ground surface by relatively impermeable strata.

When subsurface gases are found to have positive gauge pressures they can easily be extracted from the subsurface, and an accurate methane content reading can be recorded. However, with negative pressure (i.e., vacuum) relative to the atmosphere, the tendency is for atmospheric gas to move into the probe. The result is that an accurate reading of subsurface gas methane content cannot be made. Thus, a methane reading should be taken only when probe pressures are zero or positive.

To determine probe pressure, the following steps should be employed:

- Zero the gauge in the vertical position using the zero adjustment screw located in the plastic cover at the bottom of the gauge.
- Connect flexible tubing from the "high" (positive) port of the gauge (range of 0 to 0.5 in. water) to the test probe. Connections must be air-tight, and clamps should be used if necessary. If the pointer moves to the left, remove the tubing from the high port to the low port. For test probes exceeding $\pm$ 0.5 in. water, reconnect the tubing on the same port to the 0 to 5.0 in. water range gauge.

- Before recording the reading, push the tubing further on to the test probe after a period of time. If there is no sudden increase in pressure, this indicates the test probe and connective tubing are both free of foreign material that might clog these openings, and could otherwise give false readings. Record the pressure reading on the data form.
- If the pressure increases perceptively as the tubing is slid further onto the test probe, the test probe is likely clogged with foreign material, or filled with water (i.e., either condensate or ground water). This indicates that the gas between the tube blockage and the pressure indicator becomes compressed as the tube is pushed further on. The test probe and connective tubing should be separated. The end of the test probe should be inspected for water, debris, or other foreign material. If these are present, they should be removed.
- If the spurting pressure response remains, but no foreign material appears to be present, the test probe is probably filled with ground water or condensate. A peristatic hand pump should be used for approximately 10 to 15 seconds to force air into the probe and flush ground water or condensate through the bottom perforations. After this has been performed, the pressure indicator tubing should again be attached to the probe, and the procedures above repeated. If a valid reading can be obtained, it should be recorded.

Differential pressure gauges are fairly accurate devices, requiring little maintenance. For quality control purposes, checks should be made of their readings from time to time. It is suggested that instruments used regularly in the field be returned to the manufacturer every six months. This will allow accuracy checks to be made, and appropriate repairs and recalibration to be performed.

5.1.1.4 Methane monitoring

The determination of methane content is the most significant parameter of the monitoring program. Methane is colorless, odorless, explosive, and an excellent indicator of subsurface gas migration.

Combustible gas meters are available from several manufacturers. Generally, filaments inside the instrument allow measurement of combustible gases on either the percent LEL or percent gas (volume in air) scales. The scales are typically printed on the meter's face with a switch used to select the desired range.

Besides the instrument itself, inlet and outlet tubes are usually provided. The inlet tube allows connection between the meter and the gas probe being monitored. The outlet probe usually has a hand-held aspirator on it. This creates a vacuum for gases to be drawn through the meter.

To determine methane content, the manufacturer's instructions should be followed and the following general steps should be employed:

- Set the on/off switch to the on position.
- Zero the meter on both ranges alternately by following the manufacturer's instructions until the needle remains on zero when atmospheric air is drawn through the meter.
- Connect inlet tube to test probe. The connection between the instrument and test probe must be completely air-tight. Clamps should be used to ensure air-tight conditions at connection of 2 tubes.
- Set the "range" switch to the 0 to 5 percent volume in air scale. Squeeze the aspirator bulb to draw gas from the test probe into the instrument. When the needle stabilizes, record the methane reading on the data form. If the needle goes off the 0 to 5 percent volume in air scale, set the range switch to the 0 to 100 percent volume in air scale and take the reading. If the aspirator remains deflated or does not inflate within 2 seconds after squeezing, disconnect the inlet probe from the test probe. If the aspirator bulb then inflates, the test probe may be clogged and/or saturated with water. Check the water level and repeat the procedure described earlier for pressure monitoring.

Before each monitoring round, a calibration gas should be used to check the accuracy of the instrument. If recalibration or other repairs are required, the instrument should be returned to the manufacturer. Regardless of comparisons between calibration gas

gas and actual readings, the instrument should be returned to the manufacturer every six months for routine maintenance and repair.

5.1.1.5 Interpretation

To interpret gauge pressure readings and barometer conditions the following combination of possible field readings are cited:

- Gauge Pressure Positive, Barometer Falling. Under these circumstances, subsurface pressures are higher than atmospheric conditions. Monitoring personnel should get an accurate reading of any methane. This condition increases the potential for methane migration.
- Gauge Pressure Positive, Barometer Rising. This condition is unusual and it will exist for only a short time. Normally, when atmospheric barometric readings are rising, subsurface pressures lag behind, causing negative subsurface gauge pressures. As long as gauge pressure is positive, accurate subsurface methane readings are likely.
- Gauge Pressure Positive, Barometer Steady. Under these circumstances, subsurface pressures are higher than atmospheric. With barometric pressures steady, subsurface absolute pressures are likely to decrease to atmospheric levels. Field personnel should be able to take accurate subsurface methane readings.
- Gauge Pressure Negative. When subsurface gas is at a lower pressure than atmospheric, air will tend to be

drawn into the subsurface, diluting gases there. Thus accurate sampling cannot be made when subsurface gas is negative with respect to atmospheric pressure.

- Gauge Pressure 0. If this is an accurate reading and is being measured on the 0 to 0.5 in. range of the meter it should be a temporary condition. Methane meter readings should be attempted. If subsurface gauge pressure remains 0 over several days, the probe is likely clogged with condensate or moisture. A peristatic hand pump or wire should be used to unclog the tubing.

To interpret methane content readings, the following combinations of instrument readings allow evaluation of subsurface gas migration potential:

- 0 Percent LEL, 0 Percent Gas. If these readings are taken in conjunction with a positive subsurface pressure reading they are an indication that subsurface soils are truly "clean" of any combustible gases.
- 1 to 25 Percent LEL, 1 to 1.25 Percent Gas. These readings indicate that some migration of combustible gases from a SWMU may be occurring, but at sufficiently low levels that a release is not likely. However, an increase in the methane monitoring frequency may be appropriate.

- 25 to 100 Percent LEL, 1.25 to 5 Percent Gas. These levels of combustible gas indicate that a release has occurred if measured within any structure on the facility. They are reason for concern, and contingency activities should be implemented. These include increased frequency of methane monitoring, ventilation, or other emergency response measures.
- More than 100 Percent LEL, 5 to 100 Percent Gas. This indicates an emergency condition inside a structure. See Section 4.1 related to emergencies. If methane at these levels is found in the soil at the property line, a release has occurred. Some corrective actions should be implemented in the near future unless the likelihood of human exposure is remote, e.g., no occupied buildings within 1/4 mile. If these concentrations are found between a unit and the property boundary, gas migration is occurring. Some corrective actions should be planned and monitoring frequency increased.

5.1.1.6 Record Keeping

The field data form for field gas monitoring included earlier as Table 5-1 should be completed each time that monitoring activities for methane and subsurface pressures are performed in the field. These forms should be collected in a single looseleaf binder notebook. Other observations about well conditions, weather conditions, and contingency actions taken should also be recorded in the appropriate spaces for "Notes".

Field monitoring data should be evaluated by the facility owner or operator in a timely manner. If a release has occured, EPA personnel should be notified and appropriate field data forms should be transmitted.

Chronological logs should be kept for each monitoring well and each probe in the well. Review of this historical data will indicate trends of migration and will aid in predicting if and where a release may happen.

5.1.2 Indicator Constituents of Concern

5.1.2.1 General

The monitoring procedures described below are for sampling of vapor-phase (volatile) organics present in subsurface gas at a facility boundary or in ambient air within a facility structure. Several methods of sample collection are acceptable depending on site conditions, concentrations, and method of analysis. Analytical methods are not presented in this guidance. Development of a monitoring program for the indicator constituents of concern, field sampling, and subsequent laboratory analysis should be conducted by qualified personnel.

To monitor for the volatile organic constituents (VOC's) similar procedures performed during methane monitoring are appropriate. For example, probe pressures should be monitored and if negative, collection of VOC samples should not be performed. If probe pressures are positive, a VOC sample may be obtained.

5.1.2.2 Equipment

The following equipment is typically used for collection and concentration of VOC's onto adsorbent traps. Alternatively, volumetric samples can be obtained from the well probes or from within structures. Figure 5-1 illustrates a VOC sampling assembly appropriate for monitoring.

- A portable field sampling pump is necessary for VOC sample collection. The pump should be capable of operating on 110 volts AC or 12 volts DC. This portable vacuum pump should maintain constant flow for the duration of the sampling and be explosion-proof.
- An adsorbent trap appropriate to the VOC being monitored should be selected. Trap materials, sizes, and adsorbent resins are variables that qualified personnel must determine to fit site conditions. Typically, sample traps are glass or stainless steel.
- A glass-tube, variable-area flowmeter (rotameter) can be used to accurately set and maintain the gas flow rate through the sample trap. The rotameter is available through a variety of manufacturers. It should be capable of accurately measuring flows up to 30 to 50 ml per minute and include a standard needle-type metering valve. The rotameter is used during the calibration procedures to set the metering valve at the desired sampling flow rate.

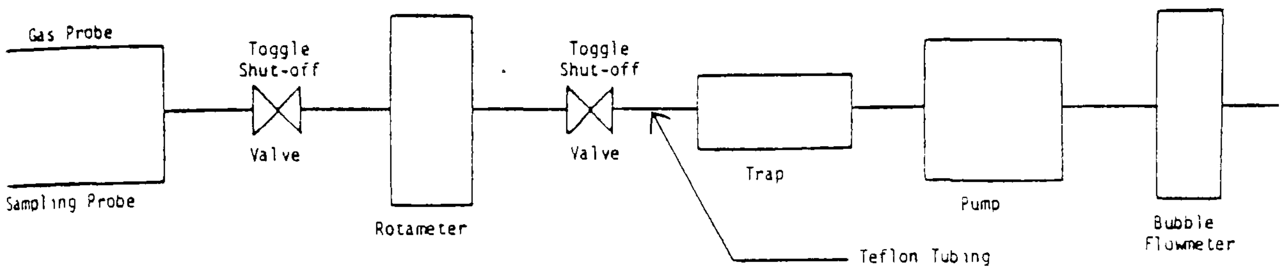


Figure 5-1

VOC Sampling Assembly

Throughout the sampling period, the rotameter serves as a check that the desired flow rate is maintained.

- A gas chromatography-type bubble flowmeter can be used to accurately calibrate the sampling assembly. While the sampling pump is intended to deliver constant flow rates from the gas probe, pressure variations may occur throughout the sampling assembly. During the initial calibration procedures, the bubble flowmeter is used to determine the gas flow rate through a calibration trap. During actual sampling, several readings are taken from the bubble flowmeter to accurately measure the flow rate through the sample trap. A 10-ml bubble flowmeter is typical for the volatile organic gas samples.
- Toggle-type shut-off valves can be placed upstream and downstream of the rotameter. These shut-off valves are used to test for a complete gas seal along the sampling assembly prior to sampling and to stop gas flow to the sample trap after the desired sampling volume has been attained.

- A spare parts box is recommended to supply the necessary replacement fittings, extra bubble flowmeter, miscellaneous tools, and special plumbing required. Assorted fittings and tools, such as screwdrivers, adjustable and open-end wrenches, tubing cutters, Teflon tape, etc., should be available.

- Teflon tubing (1/8 in. OD) is typical for small flow rates. The tubing is used to make connection between the gas probe, the rotameter, and the sample trap. Larger tubing (1/4 in. OD) may be necessary between the sample trap, the pump, and the bubble flowmeter.

5.1.2.3 Preparation of Sample Traps

The sampling traps must be prepared in the laboratory prior to field collection. This includes proper packing, sealed fittings, and "bake-out" of extraneous organic compounds. Specifically, virgin adsorbent resin should be extracted in a Soxhlet apparatus for a minimum of 18 hours prior to use. The sorbent should then be dried in a vacuum oven and subsequently sieved to provide a desired packing fraction. This fraction is used to pack the traps which are then conditioned with an inert gas flow for an appropriate time. Afterwards, they should be capped and stored.

More than a single sample should be taken at each field sampling site to ensure that a sample will be available for analysis. Sampling with adsorbent resins results in a "one-time" analysis opportunity on the laboratory instrument. When a sample is desorbed and run through the gas chromatography/mass spectrometer (GC/MS), that sample cannot be reanalyzed. At a minimum, duplicate samples must always be taken for each sampling site (gas probe). The purpose of these duplicate field samples are two-fold: (1) if a sample is lost, either during shipping or laboratory analysis, then the field duplicate serves as an identical back-up sample, and (2) for quality assurance purposes, duplicate pairs should be periodically analyzed by GC/MS to establish the precision of the sampling technique.

The size of the sample depends on the type of sample trap and the site being sampled. Often landfill and subsurface gas streams yield complex matrices of volatile organic compounds. Highly concentrated gas streams can saturate the adsorbent resin, and breakthrough occurs during sample collection. Thus, when sampling a previously unsampled site, or a site of high variability, samples should be taken at different volumes to establish the optimum sample volume for an individual site.

A permanent log of field sampling must be maintained throughout the collection period. A recommended format for data recording is shown in Table 5-2.

5.1.2.4 VOC Monitoring

To accurately sample the indicator constituents of concern, the following general steps should be employed for collecting and concentrating the VOC's.

- Label and set aside a sample trap to be used for calibration purposes only. Only one calibration trap is necessary per sampling round. This calibration trap is used to set the desired flow rate of gas through the sampling assembly at every site (gas probe).

Table 5-2

VOC Field Data Form

Date: ______________

Weather: __________________________

Barometric Pressure: ______________

Air Temperature (°F): ______________

Sampling Personnel: __________________

Trap Number	Time of Day (hr:min)	Elapsed Time for 10 ml (sec.)	Flow Rate (ml/min)	Rota-Meter Reading (ml/min)	Total Sample Time (min:sec)	Sample Volume (ml)	Sample Site		
							Well No.	Probe No.	Depth (ft)

- Prior to sampling, determine the volume and number of each type of of sample to be taken. Set aside the necessary number of traps, including traps for duplicate samples. In addition, set aside a sample trap and label it "field blank". For every 25 sample traps, two field blank traps should be set aside. Handle all of the traps in a similar manner. Use a Ziplock plastic bag to store all traps as samples are collected.
- The purpose of the field blank is to ensure that no sample contamination occurs during sample shipment and handling. The field blanks are analyzed in the laboratory, but will not have subsurface gas passed through them.
- Leak test the gas sampling using the following steps:
  - Ensure that all connections are free of dirt and moisutre.
  - Install the calibration trap. Use appropriate fittings for all connections.
  - Close the toggle valve on the rotameter's inlet side (nearest the gas probe) and turn on the sampling pump.
  - Check to see if flow is detected by the bubble flowmeter when the needle control valve of the rotameter is fully opened.
  - If flow is detected, check the entire gas sampling system for leaks. Replace Teflon tape or fittings at suspected leaks.

- As an additional check, test the second toggle valve (on the rotameter's outlet side) in the same manner.
- If a no-flow condition is detected using the bubble flowmeter, the system is free of leaks. Leak test the gas sampling assembly at each monitoring well.

- The gas flow rate can be calibrated as follows:
  - Close only the second toggle valve (on the rotameter's outlet side). The first toggle valve remains open.
  - Install the calibration trap and turn the sampling pump on.
  - Open the second toggle valve to allow subsurface gas through the sampling assembly.
  - Adjust the flow using the needle control valve on the rotameter so that a desired flow rate is established from bubble flowmeter readings. As a minimum, triplicate readings of the bubble flowmeter (start time at 0 ml and end time at 10 ml) should be used to establish the flow rate.
  - Close the second toggle valve (rotameter's outlet side), shut off the sampling pump, close first toggle valve, and remove calibration trap.
  - Do not change setting of the needle control valve on the rotameter while the series of volatile organic samples is being collected, but do calibrate the sampling assembly for each probe.
- Sample collection should be completed by following these steps:

- Select a sample trap, note the identification number in the field notebook, and install the trap in the sampling assembly. Determine and record the required sample volume.
- With the first toggle valve open and the second toggle valve closed, turn on the sampling assembly. Open the second toggle valve and start the stopwatch (one of two) to measure elapsed sampling time.
- Time and calculate the flow through the bubble flowmeter using the second stopwatch. Calculate the time to obtain the required sample volume (if different from the previous calibration test).
- Monitor the gas flow through the rotameter by visually inspecting the scale. Close the second toggle valve and stop the stopwatch at the time needed to obtain the required sample volume. Shut off the pump.
- Close the first toggle valve. Remove and securely cap the sample trap. Place trap in Ziplock bag.
- Reset the elapsed time clock/stopwatch. Repeat the above steps for all samples.

- All traps and sampling devices should be subject to similar handling, shipping, and storage conditions. A chain-of- custody from sample trap preparation through GC/MS analysis and ultimate "bake-out" must be established and strictly enforced. The chain-of-custody should be as streamlined as possible. That is, the samples should not change hands frequently, should not be shipped using unknown conditions, and should be received and analyzed in an expeditious manner.

5.1.2.5 Handling and Record Keeping

The VOC samples collected using sorbent traps must be capped with proper fittings. Each sample should be labeled appropriately with sample number, sample location, date, etc., and immediately stored in a cool, dry container. Care should be taken with regard to the integrity of the airtight seal and the storage location to avoid direct contact with heated surfaces. If the ambient temperature is expected to rise above 80°F (26.5°C) during shipment or storage, the samples should be placed in a container that can keep the samples below that temperature.

Sample analysis should be performed as soon as possible following collection. All analyses should be completed within seven days following receipt of samples in the laboratory.

5.1.2.6 Interpretation

To interpret the analytical results from VOC sampling, the laboratory should convert compound-specific concentrations to volume parts per million (Vppm). Levels detected can then be compared with compound PEL's (in Table 1-2 or 1-4) to determine if a release has occurred. As for methane, if a release is documented, EPA personnel should be notified and appropriate field and laboratory data forms should be transmitted.

5.2 CONTROL SYSTEMS

If a release has occurred, a subsurface gas control system may be required to prevent potentially harmful migration into facility structures or beyond a facility boundary. Selection or evaluation of a system to control subsurface gases must consider several site-specific characteristics including:

- Landfill, ground water, and bedrock depth.
- Age, composition, and moisture content of the waste.
- Distance to property boundary and facility structures.
- Type and location of proposed on- and off-site developments.
- Soil characteristics.
- Characteristics of cover material and final surface treatment.

Control systems can be either passive or active. In some instances, passive control systems such as interceptor trenches or barriers can provide adequate control for migrating subsurface gases. However, in general, when a facility surface or adjacent property is developed for public use, passive control methods are used as backup for an active subsurface gas control system.

5.2.1 Passive Systems

Two types of passive systems are commonly used to control gas migration from landfills and can be employed at other sites closed as landfills or possibly for underground tanks.

Passive vents provide a permeable, low resistance pathway to the surface for gases moving laterally from an SWMU. The intercepted gases are vented safely into the atmosphere.

Installation of passive vents can be by excavation of a trench, subsequently backfilled with gravel or crushed stone. An alternative is a series of well points, essentially performing the same venting function. However, well points are not always an effective control system. Passive vents are typically installed around landfill perimeters to protect adjacent areas as shown in Figure 5-2.

A passive trench barrier shields or isolates areas from subsurface gas migration by installation of an impermeable material. A passive trench barrier promotes gas venting through the more permeable soil adjacent to the trench by blocking the lateral movement of gas and forcing it to move upward to the atmosphere. This system is created by excavating a trench and backfilling it with either an impervious synthetic liner or compacted clay soil.

The advantages of passive vents and trench barriers include:

1. Operation and maintenance costs are low and initial capital costs are generally lower when compared to active gas control systems.
2. The effectiveness of passive control system is not dependent on power supply and mechanical dependability.

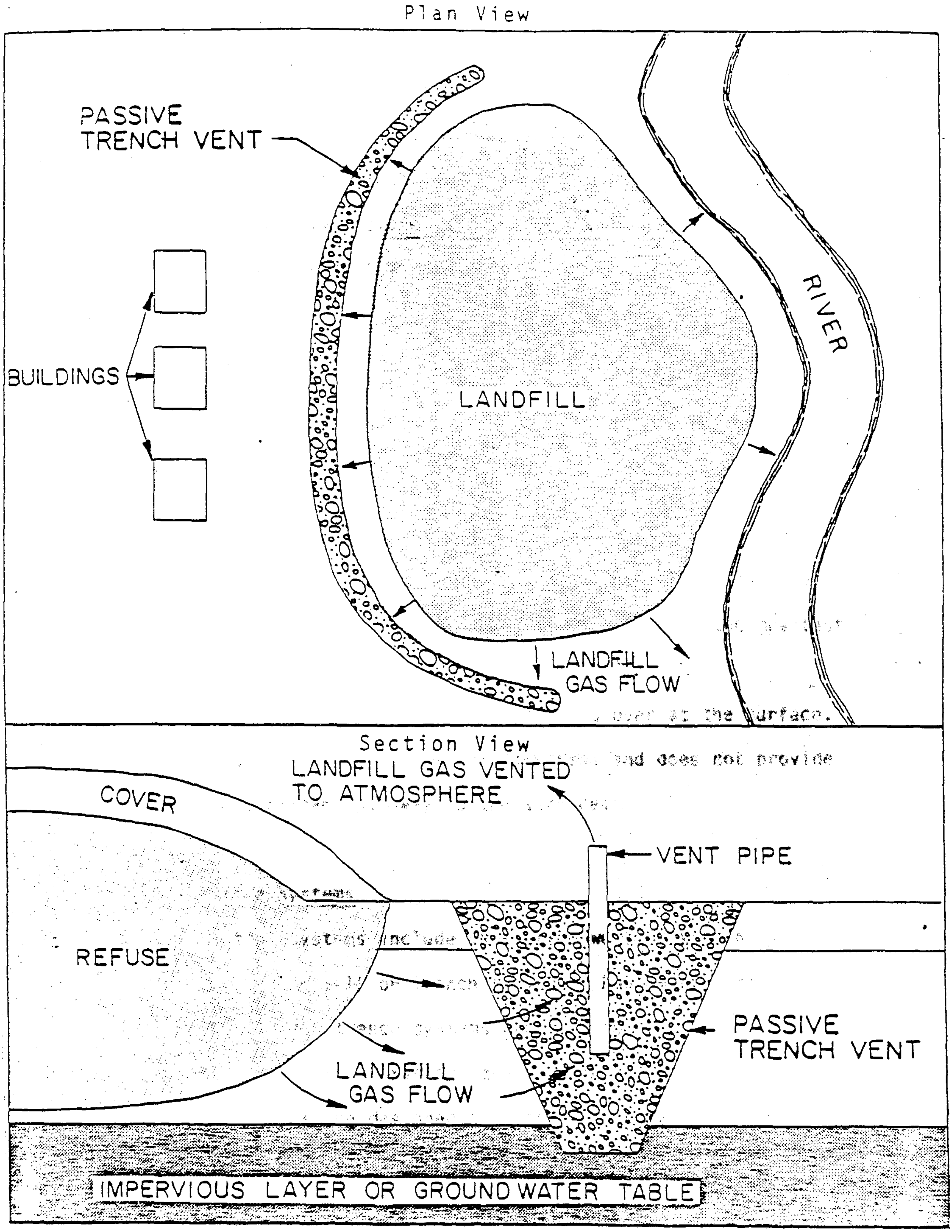


Figure 5-2

Gas Migration Control Vents

3. Passive systems do not pull surface air into the waste mass, posing a potential combustion hazard. Rather they only collect and vent migrating subsurface gases.
4. Construction methods are relatively simple.
5. A properly designed and installed passive system can provide effective gas control for many years.

Some disadvantages of passive systems include:

1. Due to construction equipment limitations, passive trench barriers become prohibitively expensive at depths greater than 30 feet.
2. Passive systems alleviate migration but do not serve as control devices unless they extend to the ground water table, to another impervious zone, or below the greatest depth of migrating gas.
3. Passive systems may become covered over at the surface. This restricts their effectiveness and does not provide a permanent pathway to the surface.

5.2.2 Active Systems

Active control systems include extraction well or trench systems and air injection well or trench systems. Perimeter extraction or injection well and trench systems are used to controll off-site gas migration. Well extraction and subslab extraction or injection systems are designed to protect on-site facilities.

5.2.2.1 Perimeter Extraction Wells

These systems consist of a series of vertical wells installed along the perimeter of the SWMU. Extraction wells are connected by a common horizonal header pipe to a suction blower. Extracted subsurface gas is subsequently vented, flared, or incinerated.

Perimeter extraction well systems are typically installed in sites 20 feet or deeper where there is little or no distance between the limits of deposited refuse and the property line or off-site facility to be protected.

The electrically driven suction blower for the perimeter system creates a negative pressure in the extraction well which is extended as a negative zone of influence into the waste around each well. Wells are spaced such that their zones of influence overlap. Gas generated or migrating into an area of influence is drawn to the wells from the soil surrounding the SWMU.

To verify system effectiveness, monitoring wells are typically installed along the property line or between the wells and the area requiring protection. Data collected from the monitoring wells are used to adjust extraction rates to obtain the desired control.

Venting collected gases may pose odor and/or air quality problems; therefore a flare may be required to combust collected gases. The cost for perimeter extraction well systems is dependent on depth and density of the waste mass, and any flaring requirements for recovered gases.

5.2.2.2 Perimeter Extraction Trench.

These systems consist of a gravel-filled intercept trench containing perforated pipe. The perforated pipe is connected by laterals to a collection header and suction blower. Collected gases are vented or flared. Perimeter trench systems are installed in natural soils, and are applicable to shallow SWMU's, 20 feet deep or less. The suction blower creates a negative pressure in the intercept trench which has an influence zone extending toward the deposited wastes. Gas migrating into this zone is drawn into the perforated pipe, and subsequently vented or flared at the blower station. The gravel trench is sealed at the surface; it extends vertically from the ground surface down to the refuse depth or to ground water, and laterally along the SWMU perimeter. Laterals connecting perforated pipe to the collection header contain valves to allow adjustment of flow. As with other control systems, monitoring wells to verify system performance are installed between the intercept trench and the property line or other location requiring protection.

5.2.2.3 Perimeter Well Injection.

These systems consist of vertical wells installed in natural soils between deposited wastes and the property line or area requiring protection. Perimeter well injection systems are typically selected for SWMU's 20 feet deep or greater and having available undisturbed soil between the limits of wastes and the area requiring protection. Injection wells are connected by a common header pipe to a blower. Air is forced through header lines and wells into the soils surrounding the landfill site, therby creating a zone of positive air pressure around each well.

Injection wells are spaced such that their zones of influence overlap, creating an air curtain along the perimeter. Gas that migrates toward this barrier is blocked by high positive pressures produced by the induction blower.

Monitoring wells are installed between the injection wells and the property line or area being protected. Adjustment of wells to evenly distribute forced air is based on test data from the monitoring wells.

Well injection systems provide gas control for deep landfills. However, they do require some undisturbed ground located between the limits of the wastes and the area requiring protection. Since this type of system is installed in natural ground, there are no problems with differential settlement. Forcing air into the system eliminates condensate and odor problems associated with extraction systems.

Reduced permeabilities in natural soils relative to the deposited wastes limit the influence area for an air injection well. More wells may be required to protect a given perimeter distance than would be required for the equivalent extraction well system located in refuse. However, air injection systems do not require a vent or flare for odor control.

5.2.2.4 Perimeter Injection Trench

These systems are similar in design to the extraction trench described above. However, air is forced into the system creating a positive air curtain barrier in the gravel trench. Air injection trenches are installed in natural soils around shallow SWMU's (20 feet deep or less), having some distance available between the refuse limits and the area requiring protection.

Air pumped into the injection trench creates a positive pressure. This pressure blocks gas migration resulting from convective forces, and dilutes gas movement resulting from diffusive flow.

5.2.2.5 On-Site Extraction Well.

Control of subsurface gas around structures located directly on the SWMU requires systems installed as an integral part of the structure. These systems must be designed to accomodate the differential settlement often experienced with landfilled wastes.

The on-site extraction well system consists of vertical extraction wells placed in refuse that are connected to a suction blower. Collected gas is vented or flared. This system is recommended when buildings are founded on piles. However, it is also applicable for buildings on floating foundations.

These well systems are typically installed in deep landfills with high generation rates. Extraction wells are located around proposed on-site structures (or the area designed for protection). The blower creates a negative pressure in the wells. Wells are spaced such that the area of influence of each well overlaps, providing a continuous draw on gases generated or migrating into the controlled area. The extraction rate is set to be slightly higher than the gas generation rate (if possible) to prevent overpulling and subsequent air infiltration in the waste mass.

The well and header systems must be designed with flexibility to accommodate the differential settlement that can occur at landfill SWMU's. Subslab monitoring probes are used to verify system performance and to aid in well adjustments. A neutral or slightly negative pressure is maintained at the ground surface to preclude gas venting or excess air movement into the waste mass. A subslab or sandwiched membrane liner is typically used as backup to provide protection during extraction system downtime. Automatic sensors can be installed inside the structures to sound alarms or actuate fans if gas concentrations reach levels indicating a release.

Deep well extraction systems, when combined with a backup passive or alarm system provide effective subsurface gas protection for on-site structures. Since these systems are located within the deposited wastes, the associated problems of settlement, condensate removal, odor, and maintenance exist. Access for maintenance and adjustment of wells must be readily available.

5.2.2.6 Subslab Gravel Bed Injection or Extraction

These systems consist of a network of perforated horizontal collection pipes installed in a gravel bed beneath the floor slabs of on-site structures. The gravel bed system is not recommended for pile-supported structures. Collection pipes are connected by header pipes to a blower where extracted gas is vented or flared. For the injection system, air is pumped to the pipes in the gravel layer.

Gravel bed systems are typically installed under structures located atop shallow fills with low gas generation rates. The suction blower creates a zone of negative pressure in the gravel bed. Gases migrating into this zone of influence are collected, and either vented to the atmosphere or flared. Monitoring and backup membrane systems are installed similar to those for the deep well extraction systems described above. Because subsurface gases may contain high concentrations of methane and be present in the subslab gravel layer, the concentration gradient necessary for diffusion will still exist. A low-permeability membrane, such as a chlorinated polyethylene material, is necessary to insure adequate protection of the structure.

In the injection system, air is forced into the gravel bed providing a zone of higher pressure and dilution. In some instances, a backup membrane may not be necessary in this type of control system.

Gravel bed systems have the disadvantage of limited access for repair. Settlement may pose problems depending on the age, depth, and composition of the deposited wastes.

In summary, both passive and active systems can be used effectively for control of gas migrating off-site to adjacent properties, or as an integral part of a facility to be constructed directly on the SWMU. Active systems involve mechanized equipment. This fact, coupled with the dynamic nature of gas generation and migration, requires that regular maintenance and monitoring be scheduled for these control systems.