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Hazardous Waste TSDF - Background Information for Proposed RCRA Air Emission Standards

Volume II - Appendices D - F

Emission Standards Division

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ABBREVIATIONS AND CONVERSION FACTORS

The EPA policy is to express all measurements in Agency documents in the International System of Units (SI). Listed below are abbreviations and conversion factors for equivalents of these units.

Abbreviations	Conversion Factor
L - liters	liter X 0.26 = gallons gallons X 3.79 = liters
kg - kilograms	kilograms X 2.203 = pounds pounds X 0.454 = kilograms
Mg - megagrams	megagram X 1 = metric tons megagram X 1.1 = short tons short tons X 0.907 = megagrams
m - meters cm - centimeters	meters X 3.28 = feet centimeters X 0.396 = inches
kPa - kilopascals	kilopascals X 0.01 = bars bars X 100 = kilopascals kilopascals X 0.0099 = atmospheres atmospheres X 101 = kilopascals kilopascals X 0.145 = pound per square inch pound per square inch X 6.90 = kilopascals
ha - hectares	hectares X 2.471 = acres acres X 0.40469 = hectares
rad - radians	radians X 0.1592 = revolutions revolutions X 6.281 = radians
kW - kilowatts	kilowatts X 1.341 = horsepower horsepower X 0.7457 = kilowatts

Frequently used measurements in this document are:

0.21	m^3	210	L	55	gal
5.7	m^3	5,700	L	1,500	gal
30	m^3	30,000	L	8,000	gal
76	m^3	76,000	L	20,000	gal
800	m^3	800,000	L	210,000	gal
1.83	kg O_2/kW/h			3 lb O_2/hp/h	
	kW/28.3 m^3			1.341 hp/10^3 ft^3	
	kPa•m^3/g•mol			0.0099 atm•m^3/g•mol	

APPENDIX D

SOURCE ASSESSMENT MODEL

APPENDIX D

SOURCE ASSESSMENT MODEL

D.1 DESCRIPTION OF MODEL

D.1.1 Overview

The standard-setting process for hazardous waste transfer, storage, and disposal facilities (TSDF) involves identifying the sources of air pollutants within the industry and evaluating the options available for controlling them. The control options are based on different combinations of technologies and degrees of control efficiency, and they are typically investigated in terms of their nationwide environmental, health, economic, and energy impacts. Therefore, information and data concerning TSDF processes, emissions, emission controls, and health risks associated with TSDF pollutant exposure are being made available for input to the review and decisionmaking process.

The Source Assessment Model (SAM) is a tool that was developed to generate the data sets necessary for comparison of the various TSDF control options. The SAM is a complex computer program that uses a wide variety of information and data concerning the TSDF industry to calculate nationwide impacts (environmental, cost, health, etc.) through summation of approximate individual facility results. It should be pointed out that the primary objective and intended use of the SAM is to provide reasonable estimates of TSDF impacts on a national level. Because of the complexity of the hazardous waste management industry and the current lack of detailed information for individual TSDF, the SAM was developed to utilize national average data where site-specific data are not available. As a result, the SAM impact estimates are not considered accurate for an individual facility. However, on a nationwide basis, the SAM impact estimates are a reasonable approximation and provide the best available basis for analysis of options for controlling TSDF air emissions.

D.1.2 Facility Processor

Information processed by the SAM includes results from recent TSDF industry surveys, characterizations of the TSDF processes and wastes, as well as engineering simulations of the relationships among: (1) waste management unit type, waste, and emission potential (emission models); (2) pollution control technology, equipment efficiencies, and associated capital and operating costs; and (3) exposure and health impacts for TSDF pollutants (carcinogen potency factors).

Inputs to the SAM calculations have been assembled into specific data files. Figure D-1 outlines the functions and processing sequence of the SAM and shows the data files used as input to the model and the output files generated by the SAM.

The facility processor is a segment of the program that accesses the SAM input files and retrieves the information/data required for a particular determination or calculation. The facility processor contains, in a series of subroutines, all the program logic and decision criteria that are involved in identifying TSDF facilities, their waste management processes, waste compositions, and volumes; assigning chemical properties to waste constituents and control devices to process units; and calculating uncontrolled emissions, emissions reductions, control costs, and health impacts. The facility processor also performs all the required calculations associated with estimating emissions, control costs, and incidence. Other functions of the SAM facility processor include performing a waste stream mass balance calculation for each process unit to account for organics lost to the atmosphere, removed by a control device, or biodegraded; testing each waste stream for volatile organic (VO) content and vapor pressure based on models of the laboratory tests; determining total organics by volatility class for each waste stream; and checking for waste form, waste code, and management process incompatability.

D.1.3 Industry Profile

Waste management processes, waste types, and waste volumes for each facility are included in the SAM Industry Profile. This file contains each TSDF name, location, primary standard industrial classification (SIC) code, and the waste volume and management process reported for that particular facility for each waste type (Resource Conservation and Recovery

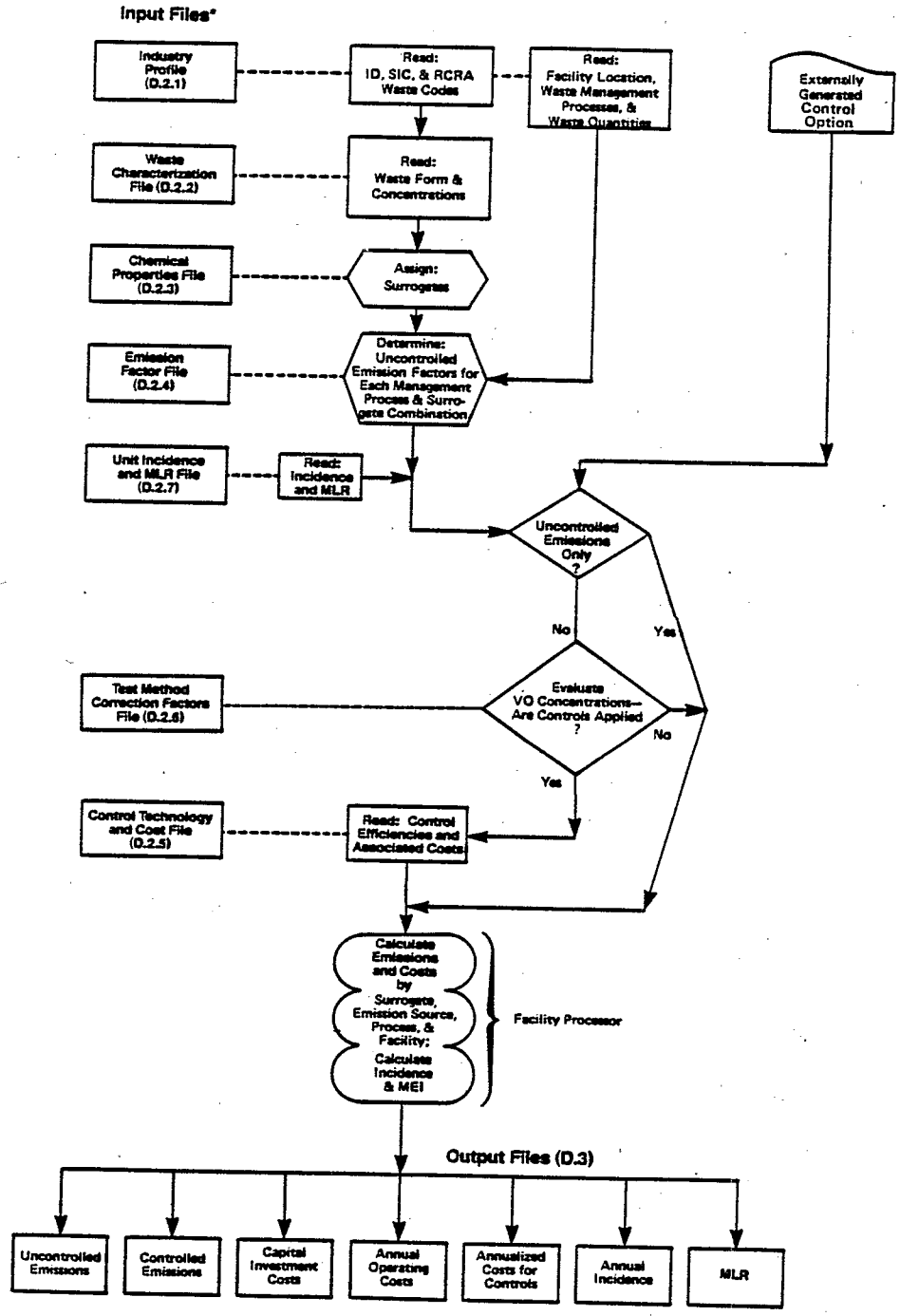

Figure D-1. Source Assessment Model flow diagram.

*The parentheses refer to the appropriate sections of Appendix D that describe in detail the SAM input files.

Act [RCRA] waste code). Where the level of detail contained in the SAM Industry Profile is not adequate for facility-specific determinations, the SAM uses estimates based on national average data. The Industry Profile contains information on the management processes that are in operation and the waste quantities that are processed at a particular facility. What is not known are the details on process subcategories within the general management process category. For example, a given quantity of waste is reported as processed by treatment tanks; because no further information is available, the SAM uses data on national averages for the distribution and use of treatment tanks to identify and assign process subcategories (i.e., covered quiescent tanks, uncovered quiescent tanks, and uncovered aerated tanks) and to distribute waste quantities treated within these subcategories for each particular facility. This nationwide averaging results in impacts that may not be accurate for an individual facility but when summed yields reasonable nationwide estimates.

The SAM facility-specific information was obtained from three principal sources. Waste quantity data were taken from the 1986 National Screening Survey of Hazardous Waste, Treatment, Storage, Disposal, and Recycling Facilities (1986 Screener).[1,2] Waste management scenarios (or processing schemes) in the SAM were based on the Hazardous Waste Data Management System's (HWDMS) RCRA Part A applications,[3] the National Survey of Hazardous Waste Generators and Treatment, Storage, and Disposal Facilities Regulated Under RCRA in 1981 (Westat Survey),[4] and the 1986 Screener. Waste types managed in each facility were obtained from all three sources. For a more detailed discussion of the TSDF Industry Profile, refer to Section D.2.1 of this appendix.

D.1.4 Waste Characterization File

The Waste Characterization Data Base (WCDB) is a SAM file that contains waste data representative of typical wastes for each industrial classification (SIC code). The SAM links waste data to specific facilities by the primary SIC code and the RCRA waste codes (waste type) identified for that facility in the Industry Profile. For those SIC codes for which no waste data were available, waste compositions were estimated using the available data bases. Waste data reported for facilities with similar processes were reviewed, and waste stream characteristics typical

of the particular process were identified. Thus, each SIC code is assigned applicable RCRA waste codes.

A RCRA waste may be generated in one of several physical/chemical forms (e.g., an organic liquid or an aqueous sludge); therefore, the RCRA waste codes were categorized in the waste characterization file according to general physical and chemical form. Each physical/chemical form of a waste code is assumed to contain the composition of chemical constituents at the respective concentrations for the RCRA waste code. The SAM uses this aspect of the WCDB to distribute waste forms within a RCRA waste code and to provide a representative chemical composition for each form of waste. The quantitative distribution of physical/chemical forms within a waste code was developed from the quantities reported in the Westat Survey data base by the physical and chemical form of the waste code.

Waste composition is used to estimate emissions on the basis of concentration and volatility of the chemicals present in the waste. Once waste form distributions are established, the SAM facility processor searches for chemical compositions to assess the volatility and emission potential of each waste code/form combination for use in emission calculations. Waste characteristics and compositions used in the SAM are derived from five existing data bases, recent field data, and RCRA waste listing background documents. It should be noted that the model waste compositions defined in Appendix C, Section C.2.2, are not used in any way in the waste characterization file or to estimate uncontrolled emissions from the industry facilities. Section D.2.2 of this appendix contains information on the development and use of the WCDB.

D.1.5 Chemical Properties File

Emission estimation on a chemical constituent basis for each of the more than 4,000 TSDF waste constituents identified in the data bases was not possible because of a lack of constituent-specific physical and chemical property data and because of the sheer number of chemicals involved. Therefore, to provide the emission models with the relevant constituent physical, chemical, and biological properties that influence emissions and still maintain a workable and efficient method of estimating emissions, waste constituent categorization was required. As a result, TSDF waste constituents were grouped into classes by volatility (based either on vapor pressure or Henry's law constant, depending on the waste management

unit process and emission characteristics) and by biodegradability. Surrogate categories were then defined to represent the actual organic compounds that occur in hazardous waste streams based on the various combinations of vapor pressure (four classes), Henry's law constant (three classes), and biodegradability (three classes). The surrogates substitute for the particular waste constituents (in terms of physical, chemical, and biological properties) in the emission calculations carried out by the SAM.

D.1.6 Emission Factors File

For each waste management process (e.g., an aerated surface impoundment), a range of model unit sizes was developed in order to estimate emissions. However, because specific characteristics of these model units were unknown, a "national average model unit" was developed to represent each waste management process. Each national unit is a weighted average of the nationwide distribution of process design parameters (e.g., unit capacity), using the nationwide frequency distribution of each model unit size as the basis for weighting. For each model unit, its emission factor (emissions per megagram of waste throughput) is multiplied by the appropriate weighting factor. The sum of these products results in a weighted emission factor for each national average model unit. The weighted emission factors were then compiled into an emission factor file for use in the SAM emission estimates. The SAM multiplies the annual quantity of organic compound processed (or passed) through the unit by the appropriate weighted emission factor for the surrogate (constituent) and management process, identified in the Industry Profile, to calculate the amount of organic compound that is emitted to the air or that is biodegraded. Because wastes may flow through a series of process units, a mass balance is performed for each waste management process unit to account for organics lost to volatilization and biodegradation in the unit; the revised organic content is then used to estimate the emissions for the next downstream unit.

D.1.7 Control Strategies and Test Method Conversion Factors

As a tool for evaluating control strategies or regulatory options, the SAM was designed to calculate environmental impacts of any number of combinations of control technologies and control efficiencies which are part of an externally generated control strategy. For example, controls

can be applied based on the emission potential of the incoming waste stream; in this case, emission potential is defined as the VO content of the waste stream. The SAM can test the stream for VO content and apply, from an established file, VO test method conversion factors to the stream to estimate the VO concentration a particular test method would detect. The waste stream VO content can then be compared to a preselected VO action level (concentration limit) to determine if controls are to be applied to the waste stream. If the waste stream exceeds the VO action level, it is controlled as part of the TSDF control strategy. The SAM then estimates emissions from each controlled management process with the appropriate technology in place. The SAM can calculate emissions in a variety of formats. Emission estimates can be presented by waste management process, waste code, waste form, and volatility class, on a nationwide level.

D.1.8 Cost and Other Environmental Impact Files

Data files have also been assembled for calculating controlled emissions, control costs, and other environmental impacts. Files were developed for the SAM that provide control efficiencies, capital investment, and annual operating costs for each control option that is applicable to a particular waste management process. Cross-media and secondary impacts for the control options are calculated external to the SAM. These are the environmental impacts that result from implementation of the air pollution control option (e.g., solid wastes generated through use of control techniques such as carbon adsorption). For cost, cross-media, and secondary impacts, control option impacts are calculated as a function of the waste quantities identified in the Industry Profile. Impact estimates were developed for a national average model unit that reflects the general frequency of national unit size characteristics for each waste management process. The impact estimates are divided by the model unit throughput to obtain a factor from which nationwide impacts are computed. Multiplying facility throughput for the management unit by the appropriate impact factor results in an estimate of the impact for the particular unit. These impacts are summed to yield national estimates.

D.1.9 Incidence and Risk File

The SAM incidence and risk file contains exposure level coefficients to estimate annual cancer incidence and maximum lifetime risk (MLR) for the population within 50 km of each TSDF. The coefficients were developed using the Human Exposure Model (HEM) with 1980 census population distributions, local meteorological/climatological STAR data summaries, and an assumed emission rate (10 Mg/yr) and unit risk factor (1 case/$\mu g/m^3$/person). The SAM facility-specific incidence and risk coefficients can be scaled by annual facility emissions and the appropriate unit risk factor to give health impact estimates that reflect the level of emissions resulting from a particular emission scenario or control option. For a more detailed examination of incidence and risk determinations, see Appendix E.

D.2 INPUT FILES

D.2.1 Industry Profile Data Base

D.2.1.1 Introduction. As an initial input to the estimation of air emissions, an Industry Profile was developed to characterize TSDF waste management practices. The Industry Profile is based on data from the Westat Survey and from EPA's HWDMS. Data from the Office of Solid Waste's (OSW) 1986 Screener, which reflect 1985 TSDF activities, are also used heavily.

The following sections describe the Industry Profile contents and outline the data base sources. Discussion centers on the current Industry Profile of 2,336 TSDF. Section D.2.1.2 describes the data base structure and contents, Section D.2.1.3 documents selection of the SAM TSDF universe, and Section D.2.1.4 reviews data sources.

D.2.1.2 Data Base Contents. Table D-1 lists the variables in the current Industry Profile. Each record in the Industry Profile constitutes a single waste stream. A facility may have several different waste streams. The variables following the waste code indicate quantities and management methods for TSDF operations. All quantities are expressed in megagrams per year (Mg/yr).

Table D-2 gives an example record of an Ohio TSDF with EPA identification number OHD000000000 (variable FCID). Its primary SIC code is designated as 2879 (SIC1, Pesticides and Agricultural Chemicals). Table

TABLE D-1. INDUSTRY PROFILE DATA BASE CONTENTS[a]

Variable	Description
FCID	EPA 12-digit facility identification number
SIC1	Primary 4-digit standard industrial classification (SIC) code
WSTCDE	EPA hazardous waste number (RCRA waste code)
WAMT	Amount of waste for WSTCDE (Mg/yr)
QTYSTR	Amount of waste stored (Mg/yr)
TYPSTR	Storage process(es) - one of 20 potential process combinations[b]
QTYTX	Amount of waste treated (Mg/yr)
TYPTX	Treatment process(es) - one of 19 potential process combinations[b]
QTYDIS	Amount of waste disposed (Mg/yr)
TYPDIS	Disposal process(es) - one of 11 potential process combinations[b]
SOURCE	Source of data for waste quantities, RCRA codes, and management methods
ELIGSTAT	Facility status
LATT	Latitude (expressed in degrees, minutes, seconds, and tenths of seconds)
LONG	Longitude (expressed in degrees, minutes, seconds, and tenths of seconds)

RCRA = Resource Conservation and Recovery Act.
Mg = Megagrams.

[a]This table identifies and describes those variables of the Industry Profile data base used to characterize treatment, storage, and disposal facilities in nationwide impacts modeling.

[b]Hazardous waste management process combinations are presented in Table D-3.

TABLE D-2. INDUSTRY PROFILE DATA BASE - EXAMPLE RECORD[a]

Variable	Contents
FCID	OHD000000000
SICC1	3879
WSTCDE	D001[b]
WAMT	1056954
QTYSTR	1056954
TYPSTR	1
QTYTX	1056954
TYPTX	10
QTYDIS	0
TYPDIS	0
SOURCE	2
ELIGSTAT	7
LATT	3115000
LONG	08758000

[a]An example record of how one facility waste stream would appear in the Industry Profile data base.

[b]D001 = ignitible waste. Source: 40 CFR 261.21, Characteristic of ignitibility.[5]

Ignitible wastes identified as D001 (WSTCDE) are managed at this facility. This TSDF manages (WAMT) and stores (QTYSTR) 1,056,954 Mg of waste D001 in a tank (TYPSTR = 1--see Table D-3), but it also treats the same amount (QTYTX = 1,056,954 Mg) in a tank (TYPTX = 10--see Table D-3). No quantity of this waste is disposed of (QTYDIS and TYPDIS, respectively). The data source for the RCRA waste code, its fraction of the total TSDF waste quantity, and its management processes may have come from EPA's HWDMS (SOURCE = 2, 3, or 4). Another source of such data may include the Westat Survey (SOURCE = 1). OSW's 1986 Screener (SOURCE = 5 or 6) provided the total waste quantity managed in 1985--from which the waste code quantity was derived--along with verification of waste management processes active in 1985. The facility operating status code (ELIGSTAT) indicates the TSDF is an active TSDF, ELIGSTAT = 7 (former TSDF, ELIGSTAT = 1; or closing TSDF, ELIGSTAT = 3). Latitude (LATT) of the site is 31 degrees, 15 minutes, and no seconds, and the longitude (LONG) is 8 degrees, 75 minutes, and no seconds.

The Industry Profile contains the following waste management processes found under variables TYPSTR (storage), TYPTX (treatment), and TYPDIS (disposal):

- Storage in a container (S01), tank (S02), wastepile (S03), or surface impoundment (S04)
- Treatment in a tank (T01), surface impoundment (T02), incinerator (T03), or other process (T04)
- Disposal by injection well (D79), landfill (D80), land application (D81), or surface impoundment (D83).

A variety of management process combinations may occur at facilities, some of which one would expect to find in parallel or in series. Where a series representation in the Industry Profile is not appropriate, the SAM is programmed to divide streams evenly between or among the listed processes. All potential process combinations found in the Industry Profile are listed in Table D-3 with the assigned divisions. The processes in column 2 become the parallel or series-parallel processes in column 3. Note that T04 ("other treatment") is listed separately, but its emissions are calculated on the basis of T01 (treatment tanks) operation. T03 (incineration) and D79 (injection well) are listed, but the SAM only calculates their transfer

TABLE D-3. INDUSTRY PROFILE REFERENCE KEY FOR WASTE MANAGEMENT PROCESS COMBINATIONS[a]

Combination number	Process code description[c]	Waste flow used in modeling simulation
Storage Processes (variable TYPSTR in Table D-1)		
0	No storage	No Storage
1	S02 only	→ S02
2	S01 only	→ S01
3	S04 only	→ S04
4	S03 only	→ S03
5	Other storage	→ S01
6	S01, S02	→ S01 → S02
7	S01, S04	→ S01 → S04
8	S01, S02, S03	→ S01 → S02 → S03
9	S01, S03	→ S01 → S03
10	S01, S02, S04	→ S01 → S02 → S04
11[b]	S01, S04	→ S01 → S04
12[b]	S01, S03, S04	→ S01 → S04 → S03
13[b]	S04, sump	→ S04
14[b]	S02, other	→ S02 → S01
15	S03, S04	→ S03 → S04
16	S02, S03	→ S02 → S03
17[b]	S02, S03, S04	→ S02 → S03 → S04

See notes at end of table. (continued)

TABLE D-3 (continued)

Combination number	Process code description[c]	Waste flow used in modeling simulation
Storage Processes (con.)		
18	S02, S04	→ S02 → S04
19[b]	S01, S02, S03, S04	→ S01 → S02 → S03 → S04
20	S01, S02	→ S01 → S02
Treatment Processes (variable TYPTX in Table D-1)		
0	No treatment	No treatment
1	T01 only	→ T01
2	T02 only	→ T02
3	T03 only	→ T03
4	T04 only	→ T04
5	T01, T02	→ T01 → T02
6[b]	T01, other	→ T01 → T04
7[b]	T01, other	→ T01 → T04
8	T01, T03	→ T01 → T03
9[b]	T03, other	→ T03 → T04
10	T01, T02, T03	→ T01 → T02 → T03
11[b]	T01, T03, other	→ T01 → T04 → T03
12	T02, T03	→ T02 → T03
13	T02, T04	→ T02 → T04

See notes at end of table.

(continued)

TABLE D-3 (continued)

Combination number	Process code description[c]	Waste flow used in modeling simulation
Treatment Processes (con.)		
14[b]	T01, T02, T03, T04	→ T01 → T02 → T04 → T03
15	T01, T04	→ T01 → T04
16	T03, T04	→ T03 → T04
17	T01, T02, T04	→ T01 → T02 → T04
18	T01, T03, T04	→ T01 → T03 → T04
19	T02, T03, T04	→ T02 → T04 → T03
Disposal Processes (variable TYPDIS in Table D-1)		
0	No disposal	No disposal
1	D79 only	→ D79
2	D80 only	→ D80
3	D83 only	→ D83
4	D81 only	→ D81
5	Other	→ D80
6	D81, D83	→ D81 → D83
7	D80, D83	→ D80 → D83
8[b]	D79, D83	→ D79 → D83
9[b]	D79, D81	→ D79 → D81
10	D80, D81	→ D80 → D81

See notes at end of table. (continued)

TABLE D-3 (continued)

Combination number	Process code description[c]	Waste flow used in modeling simulation
Disposal Processes (con.)		
11	D79, D80	→ D79 → D80

[a]This table presents the various combinations of processes a waste code may pass through at a facility. Column 3 depicts how waste code combinations are interpreted to simulate actual facility processing steps in the Source Assessment Model. In many cases, it is unlikely that processes occur in series due to the physical form of the waste or the type of process; therefore, many management trains are interpreted in the model as having one waste pass through processes in parallel.

[b]Sources currently are not found in the Industry Profile data base but could potentially occur.

[c]Process code descriptions:[6]

Storage		Treatment		Disposal	
S01	Container	T01	Tank	D79	Injection well
S02	Tank	T02	Surface impoundment	D80	Landfill
S03	Wastepile	T03	Incinerator	D81	Land treatment
S04	Surface impoundment	T04	Other	D83	Surface impoundment

and handling emissions. This is because a separate Agency program is under way to regulate air emissions from hazardous waste incineration and because there are no process air emissions from injection wells.

The Industry Profile also contains RCRA waste codes as defined in Title 40, Part 261, of the Code of Federal Regulations (CFR).[7] The data base contains over 450 waste codes and includes "D," "F," "K," "P," and "U" RCRA codes. Hazardous waste codes are described in more detail in Chapter 3.0.

D.2.1.3 Establishing the SAM Universe of TSDF. The 1986 Screener surveyed over 5,000 potential TSDF. The Screener identifies 2,221 "active" TSDF to be characterized in the SAM. An active facility treated, stored, disposed of, or recycled waste during 1985 that was considered hazardous under Federal RCRA regulations. Active facilities include TSDF filing for closure if the facility managed some waste in 1985. The Screener designates as "inactive" those facilities that fall into any of three other categories:

- Former TSDF that have ceased all hazardous waste management operations
- TSDF that are closing and did not manage waste in 1985
- Facilities that do not treat, store, dispose of, or recycle hazardous waste.

Active Screener TSDF that are not currently addressed in the SAM were excluded. Excluded TSDF represent:

- TSDF that manage polychlorinated biphenyls (PCB)--a waste that is currently not RCRA hazardous
- TSDF whose waste is hazardous under State RCRA regulations but not under Federal RCRA rules
- TSDF that treat waste in units exempt from RCRA or store it under the 90-day rule (40 CFR 262.34(a))[8] and, therefore, do not require RCRA permits

TSDF whose total waste amount managed (including storage, treatment, and disposal) is less than 0.01 Mg/yr (about 340 TSDF) were considered small potential emitters and were also excluded from the SAM to improve data base manageability. A total of about 340 TSDF were excluded due to either

0.01-Mg/yr cutoff or because they only managed State-designated hazardous waste. Another nine active TSDF were excluded from the Industry Profile because all available data are classified as Confidential Business Information (CBI). The impact on nationwide waste volume from these nine TSDF is considered small due to their low volumes (less than 0.5 percent of the waste volume managed nationwide).

In addition to currently active TSDF, former or closing TSDF that had land disposal operations were also profiled. This is because of the potential source for air emissions from TSDF closed with waste left in place. The Westat Survey, HWDMS, and 1986 Screener identified 115 TSDF with former or closing land disposal operations. Therefore, the total universe for the SAM was set at 2,336 TSDF (2,221 active TSDF plus 115 closing or former TSDF).

D.2.1.4 Data Sources. The Industry Profile represents a composite of waste-stream-specific information collected from the 1986 Screener, the Westat Survey, and HWDMS. This section describes each of these sources. Waste stream data for each facility were derived from these sources as shown in Table D-4.

TABLE D-4. INDUSTRY PROFILE DATA BASE: DISTRIBUTION OF FACILITIES AMONG DATA SOURCES[a]

Data source	Number of active TSDF	+	Number of closed or former TSDF with land disposal units	=	Total TSDF
Westat Survey	438		27		465
HWDMS	1,361		85		1,446
1986 Screener	422		3		425
Total	2,221		115		2,336

TSDF = Treatment, storage, and disposal facility.
HWDMS = Hazardous Waste Data Management System.

[a]This table shows the number of facilities for which each Industry Profile data source provides waste stream information.

The 1986 Screener was used to identify the universe of regulated TSDF and their waste quantities managed annually. The Screener data base contains the most current data on TSDF operations--data from the year 1985. However, specific waste codes and the processes by which they are managed at each facility are not contained in the data base. Therefore, two other sources of waste code data were used. The Westat Survey was the preferred data source for assigning RCRA waste codes and management processes and distributing waste quantities by process. But due to the Westat Survey's limited sample of 831 TSDF, it was necessary to access the HWDMS RCRA Part A permit application data. The 1986 Screener was also used to verify management processes in operation and describe a TSDF's waste streams and management processes if the Westat Survey or the HWDMS data did not contain the information needed.

The Westat Survey and the HWDMS were used as initial inputs to assigning an SIC code to each facility. Section D.2.1.4.4 outlines additional sources used to determine a facility's principal business activity.

D.2.1.4.1 <u>1986 Screener data</u>. The goals of using the 1986 Screener data were threefold: (1) to identify which TSDF should be included in the SAM, (2) to profile 422 active TSDF identified by the Screener but not included in the HWDMS or the Westat Survey, and (3) to update the total waste quantity by TSDF to reflect 1985 data.

As a first goal, the Screener data on TSDF operating status were compared to the Industry Profile list of active and closed facilities. Any inconsistencies in the profile were revised, using the 1986 Screener information as the most current source of data.

The second goal--to profile the additional Screener TSDF--entailed adapting the Screener data to make them compatible with the HWDMS and the Westat Survey. The 1986 Screener does not refer to individual RCRA waste codes but rather to general waste types: acidic corrosives, metals, cyanides, solvents, dioxins, other halogenated organics, and other hazardous waste. Also, management processes listed in the Screener differ slightly from the processes cited in the HWDMS and the Westat Survey. For instance, the 1986 Screener does not list storage in tanks or containers, specifically. Rather, these are combined in a category listed as "other storage."

To adapt these Screener data, default waste categories were developed to replace RCRA waste codes, and management process descriptions were converted to RCRA process codes. For example, the 1986 Screener waste type "acidic corrosives" was assigned to a default RCRA waste code of D002 (corrosive waste). Cyanides were assigned to D003 (reactive waste). (Section D.2.2.10 describes the development of default waste compositions.) For waste management processes, most process code assignments were straightforward; however, some process descriptions were not. For example, the Screener's wastewater treatment category was assigned the process code T01 (treatment in a tank) when not specified as exempt from RCRA regulation. Other processes included solidification, which was assigned T04 (other treatment), and "other storage," which was assigned a combination of S01 and S02 (storage in a container or tank).

After assigning management processes and RCRA waste codes to each facility, the next step used to develop Screener waste streams was to assign specific waste quantities to RCRA waste codes and management processes. Question 3 of the Screener indicated the total amount of waste that was treated, stored, or disposed of onsite in units regulated under RCRA at each facility. Quantity distributions were made based on information obtained from the 1986 Screener, telephone inquiries conducted by the Screener staff, and best engineering judgment.

The third goal in using 1986 Screener data was to update waste quantities (derived from the HWDMS or the Westat Survey) for the active TSDF. Screener Question 2 was used to identify the total quantity of hazardous waste that was treated, stored, or disposed of onsite in 1985 under Federal RCRA regulations. The 1985 total quantity of waste per facility was distributed among waste streams on a weight basis. 1985 distributions were made proportionate to the TSDF's distribution of waste code quantities used previously from either the HWDMS or the Westat Survey. For example, if a facility had a waste code quantity of 1,000 Mg and a total waste quantity for the facility of 2,000 Mg, the distribution of waste code to total waste quantity is 1,000/2,000 or 0.5. If Screener data indicate that the facility has a 1985 total waste quantity of 3,000 Mg, the waste code quantity is increased from 1,000 to 1,500 Mg to reflect its ratio to the facility's total waste quantity (0.5 multiplied by 3,000).

D.2.1.4.2 Westat Survey. Data were accessed from Westat's general questionnaire to identify facility waste streams. Question 12 asked for the total quantity of hazardous waste that the facility treated, stored, or disposed of onsite during 1981. Question 17 asked the facility to complete a table for the 10 hazardous wastes handled in largest volume in 1981. The table requested that the waste be listed by EPA waste code and include a breakdown of waste by specific management processes (e.g., tank, incinerator, wastepile) and by specific waste quantities for storage, treatment, and disposal. The Westat Survey is preferred to HWDMS as a data source because data reflect actual annual throughputs and waste management processes for TSDF. However, the data base covered only 831 TSDF. Of these, only 438 active and 27 closed TSDF were of interest. Also, data represent activities in the year 1981 and may no longer be accurate. Westat Survey data have been reviewed to exclude hazardous wastes that are exempt or excluded from RCRA regulation. The Westat Survey specifically excludes waste streams sent to publicly owned treatment works (POTW), waste from small quantity generators, wastes that are stored in containers or tanks for less than 90 days, wastewater treatment in tanks whose discharges are covered under National Pollutant Discharge Elimination System (NPDES) permits, and wastes that have been delisted by EPA even if the delisting occurred after 1981.[9]

D.2.1.4.3 HWDMS. HWDMS data, retrieved in October of 1985, consist largely of RCRA Part A permit application information. Existing TSDF were required to complete Part A of the permit application by November 19, 1980, in order to receive interim status to operate. The Part A permit asks the facility to list quantity of waste (by RCRA waste code) that will be handled on an annual basis and waste management processes that will be used.

HWDMS data have several disadvantages compared to Westat Survey data. Unlike the Westat Survey data, Part A reflects estimated, not actual, waste throughput and processes. Part A is a record of "intent to manage" waste. The HWDMS also does not break down the total amount of waste managed into quantities that were treated, stored, or disposed of, and the year for which data are provided is unknown. A facility may have submitted an

amended Part A to reflect changes in waste types or quantities since 1980, but the date of submission cannot be ascertained. Finally, some waste streams may reflect processes that are exempt or excluded under RCRA, such as less than 90-day storage. These streams cannot be identified.

D.2.1.4.4 SIC codes development. Each of the TSDF in the Industry Profile was examined individually to determine a primary 4-digit SIC. In assigning SIC, the HWDMS and Westat Survey were used as initial points of reference, but because of the number of nonexistent codes and the abundance of only 2- or 3-digit SIC codes, each SIC was verified using all available reference sources.

Several steps were taken to assign an SIC code. The Standard Industrial Classification Manual[10] was used to identify SIC codes for TSDF when no code was provided in the data sources, and the facility's name, address, waste codes, and waste amounts were examined for identifying information. In many instances, this information was enough to assign an SIC. For example, a facility, Wood Preserving Company B, was assigned an SIC of 2491 (wood preserving industries). A facility with waste codes of K048-K052 would be assigned an SIC relating to the petroleum refining industries. Additional sources of information[11,12,13] provided corporate or plant descriptions. Also, the various census reports[14-18] were used to identify the number of facilities in each State with a given SIC code. For example, in trying to establish an SIC for Oil Service Company C in Arizona, waste codes were referenced first. No "K" waste codes were identified that related the facility to petroleum refining. Therefore, the Census of Manufactures[19] was consulted. It indicated zero petroleum refineries in Arizona. Oil Service Company C was assigned the SIC of 5172 (petroleum products not elsewhere classified).

D.2.2 TSDF Waste Characterization Data Base (WCDB)

D.2.2.1 Background. To support the development of air emission regulations for hazardous waste TSDF, a data base of waste characteristics was developed. Wastes listed in this data base were characterized, primarily using five existing data bases: (1) the Westat Survey,[20] (2) the Industry Studies Data Base (ISDB),[21] (3) a data base of 40 CFR 261.32 hazardous wastes from specific sources[22] (i.e., waste codes beginning with the

letter K), (4) the WET Model Hazardous Waste Data Base,[23,24] and (5) a data base created by the Illinois EPA.[25] An additional source of data, EPA field reports on hazardous waste facilities, also was used. The WCDB makes no use of the model wastes defined in Appendix C, Section C.2.2.

The Westat Survey data base contains the most extensive information on the physical/chemical form, quantity, and management of waste; therefore, it was selected to serve as the framework for the TSDF WCDB. This data base has been organized to present hazardous waste stream* information in the following series of categories:

- Primary SIC code
- RCRA waste code
- General physical/chemical waste form.

For each SIC code, Westat contains a list of waste codes. It then divides each waste code into physical/chemical forms such as inorganic sludges, organic liquids, etc. Westat also designates a waste quantity for each physical/chemical form of a waste code.

The remaining four data bases and EPA field reports were used to provide chemical composition data in the form of two additional data categories in the WCDB: "waste constitutents" and "percent composition of constitutents." Where information was not available for these two categories, a list of constitutents and their percent compositions was created (i.e., default composition) based on information found in the four data bases, field reports, RCRA waste listing background documents, and engineering judgment.

Table D-5 is an example of a hazardous waste stream in the WCDB. This example states that, in the commercial hazardous waste management industry (SIC code 4953), RCRA waste code U108 is managed as an organic liquid (form 4XX). Its composition is 90 percent 1,4-dioxane and 10 percent water.

D.2.2.2 Application to the Source Assessment Model (SAM). The SAM uses the WCDB to identify representative compositions for wastes managed at each TSDF. SAM uses these compositions to estimate organic emissions based on waste constituent concentrations and their volatility. The procedure is described in the following paragraphs.

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*For discussion, a hazardous waste stream is a unique combination of SIC code, RCRA waste code, and physical/chemical form.

TABLE D-5. WASTE CHARACTERIZATION DATA BASE: EXAMPLE WASTE STREAM RECORD[a]

SIC code	4953
Form code[b]	4XX
RCRA characteristic code[c,d]	T
RCRA waste code[d]	U108
Waste constituent/% composition	1,4-Dioxane/90%
	Water/10%

SIC = Standard industrial classification.
RCRA = Resource Conservation and Recovery Act.

[a]This table presents an example of the information found in the Waste Characterization Data Base for one waste stream managed in a given industry.

[b]Physical/chemical waste forms are coded as follows:

1XX = Inorganic solid
2XX = Aqueous sludge
3XX = Aqueous liquid
4XX = Organic liquid
5XX = Organic sludge
6XX = Miscellaneous.

[c]RCRA characteristic code reflects the hazard of the waste:

T = Toxic
C = Corrosive
I = Ignitible
R = Reactive.

[d]RCRA characteristic and waste codes listed in 40 CFR 261.33(f).[26]

The SAM initially reads the Industry Profile (described in Section D.2.1) for each TSDF's primary SIC code, RCRA waste codes, and the annual quantity of each code. It then searches the WCDB for this SIC and then for the TSDF's RCRA waste codes. Because the physical and chemical form of a waste code may vary, the chemical composition and emission potential will also vary. Therefore, for each waste code, the WCDB provides quantities from the Westat Survey data base by physical/chemical form of the waste code. The quantitative distribution of physical/chemical forms within a waste code is then applied to the Industry Profile waste code's quantity for that TSDF. For example, if the TSDF's profile has 150 Mg of D003 and the WCDB shows that D003 has 1,200 Mg of organic liquid and 600 Mg of organic sludge forms present across that SIC (i.e., a two-to-one ratio by form), the TSDF profile's 150 Mg is distributed two-to-one as 100 Mg of organic liquid and 50 Mg of organic sludge. This approach allows the most current waste quantity information to be used in a more detailed fashion, using distribution data from a more rigorous data source (Westat Survey).

Once form distributions are established, the SAM begins to search for chemical compositions to assess volatility and, in turn, emission potential of each waste code/form combination. The search proceeds as depicted in Figure D-2. Six discrete sets of waste composition data are identified in the figure:

- ISDB
- Field data
- Illinois EPA data base
- K Stream data base
- WET Model data base
- Data set consisting of default values.

The logic shown in Figure D-2 ranks these data sets in the order listed above to reflect the relative certainty in data representativeness. Thus, if a waste stream had more than one set of compositions to choose from, the SAM would use the highest ranking data base composition. The logic diagram does not include the Westat Survey constituents because no percent compositions were available.

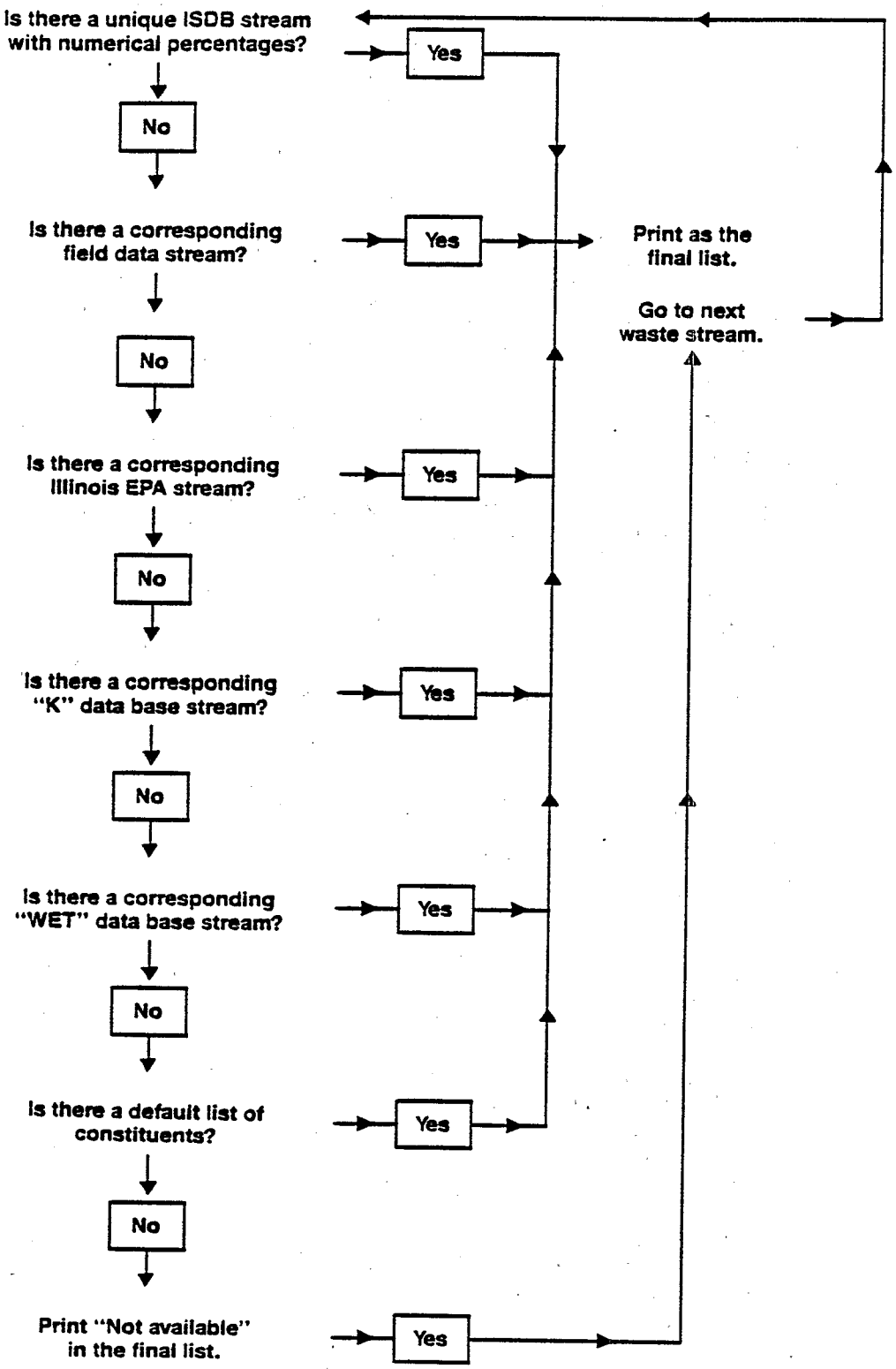

Figure D-2. Logic flow chart for selection of final list of waste constituents.

Sections D.2.2.4 through D.2.2.10 discuss each of the five existing data bases, EPA's field data base, and the default values established.

D.2.2.3 Limitations of the WCDB. The limitations of this WCDB coincide with those found in all contributing data bases. Therefore, some of the same weaknesses were shared:

- Compositional data were not available from the existing data bases on each SIC code/waste code/waste form combination (also referred to as a "waste stream"). Therefore, it was necessary to assign compositions (i.e., default compositions) to 30 percent of the organic waste streams. This reduces the certainty of actual waste compositions the SAM uses for SIC codes.

- The data base consisted of 1981 waste codes (the year the Westat Survey was conducted). It did not reflect additions to 40 CFR 261[27] since 1981 such as listing of dioxins. However, wastes delisted since 1981 have been eliminated from the WCDB. Thus, the SAM emission estimates reflect delisting of wastes but not the role of wastes listed since 1981.

- Certain organic constituents are generic chemical classes, e.g., "amino alkane," and thus do not have specific physical and chemical properties. Therefore, volatility and biodegradation classes were designated for these generics by referencing a common chemical considered representative of that generic chemical. Therefore, the presence of generic classes in the WCDB decreases the SAM's certainty of predicting appropriate emissions from that class.

D.2.2.4 Westat Survey Data Base. This survey data base compiles data from a 1981 EPA survey of all hazardous waste generators and TSDF. Use of the data base for this project focused on TSDF only.

The Westat Survey data base contains information on TSDF from approximately 230 SIC codes, covering active and closed TSDF. A subset of the data base was used to develop the TSDF WCDB. This subset represents only the active facilities in the Westat data base (covering 182 SIC codes). The active facilities constitute about 70 percent of the complete Westat data base, and closed facilities make up the remaining 30 percent.

D.2.2.4.1 Use of the Westat data base. As stated in Section D.2.2.1, the Westat data base provides the SAM (1) quantitative distributions of physical/chemical forms of waste codes, and (2) the framework for the SAM to track a waste code to an appropriate chemical composition in the WCDB.

(Compositions are selected from the data bases described in Sections D.2.2.5 through D.2.2.10.)

The WCDB uses Westat waste stream information such as facility SIC code, RCRA waste codes managed, and physical/chemical forms of waste codes (i.e., waste streams). This information is organized by SIC so that data can be applied to any TSDF in the Industry Profile with that SIC code.

The WCDB and the SAM use the following Westat data base categories:

- SIC code--Primary SIC code of the survey respondent. If the respondent's primary SIC code was 2-digit, e.g., 2800, the more detailed, secondary SIC code listed by the respondent was used when available, e.g., 2812. (For all remaining 2-digit codes, more descriptive 4-digit codes were assigned to the WCDB based on knowledge of the TSDF's industrial operations.)

- RCRA waste code--Survey respondents were asked to list the 10 largest waste streams (by RCRA waste code) managed at each TSDF. Thus, for each SIC code, TSDF respondents with a matching SIC will have their top 10 waste codes listed.

- Physical/chemical waste form--Survey respondents were also asked to describe the physical/chemical character of each of the 10 waste streams. Based on these descriptions, the physical/chemical forms were classified as follows:

1XX	Inorganic solid	4XX	Organic liquid
2XX	Aqueous sludge	5XX	Organic sludge/solid
3XX	Aqueous liquid	6XX	Miscellaneous

  Therefore, within a SIC's waste code, one will find as many as six forms of that waste code.

- Physical/chemical waste form quantity--The quantity of each physical/chemical form of a waste code managed within each SIC code. (Note: These form quantities are mutually exclusive of each other and may be added.) If more than one TSDF reported the same form of waste code, their quantities were added to provide an indication of the volume of that stream managed by the TSDF population having a common SIC code.

D.2.2.4.2 Westat Survey Data Base limitations. Certain limitations of the Westat Survey data base that may affect the SAM results are discussed below:

- Several survey respondents identified wastes by using more than one waste code. The EPA entered these streams into the Westat data base as X---codes. For the WCDB, the X codes were translated into their respective D, F, K, P, and U waste codes, and the first code listed from the multiple codes was used in the WCDB. For example, if X002 is a combination of F003 and F005, then F003 was used in the WCDB. Not knowing which code best represented a waste increased the uncertainty of waste compositions used in the SAM.

- Individual waste streams were not always keyed to their most descriptive SIC code. The WCDB identifies waste streams by the primary SIC code listed by a TSDF. Consequently, it is possible that a waste stream will be identified by the facility's primary SIC code when another SIC code is more descriptive. To correct this limitation, the most descriptive SIC codes were chosen following an Industry Profile review of facility SIC codes.

- Invalid or missing codes were found in the Westat data base. For example, the Westat data base may have no SIC codes listed for some TSDF, invalid RCRA waste codes listed such as "D000, 9995, 9998, 9999, Y---," and no physical/chemical form of waste listed.

  To examine those Westat Survey waste streams with invalid waste forms and waste codes (9999, etc.), a list of such codes was generated. Then, it was decided to remove some of these streams from the WCDB and reassign real waste codes to the remaining streams based on an examination of waste constituents and waste form. The following summarizes steps taken to resolve invalid waste codes and forms:

  -- For invalid waste codes:

     --Streams <18.9 Mg (5,000 gal) were not included in the WCDB.

     --Streams <18.9 Mg but containing PCB were reassigned.

     --Streams >18.9 Mg but containing no constituent information were not included.

     --Streams >18.9 Mg and having useful constituent information were reassigned.

  -- For waste streams with no physical/chemical form listed:

     --Streams <18.9 Mg were not included in the WCDB.

--Streams having no constituents were not included.

--Management method(s) were reviewed for a clue as to the liquid, sludge, or solid state. Then, physical/chemical forms were assigned to such streams.

D.2.2.5 Industry Studies Data Base. The ISDB is a compilation of data from EPA/OSW surveys of designated industries that are major hazardous waste generators. The ISDB version used addresses eight SIC codes:

- Industrial inorganic chemicals - alkalies and chlorine (SIC 2812)
- Industrial inorganic chemicals - not elsewhere classified (SIC 2819)
- Plastics materials, synthetic resins, and nonvulcanizable elastomers (SIC 2821)
- Synthetic rubber (SIC 2822)
- Synthetic organic fibers, except cellulosic (SIC 2824)
- Cyclic crudes, and cyclic intermediates, dyes, and organic pigments (SIC 2865)
- Industrial organic chemicals, not elsewhere classified (SIC 2869)
- Pesticides and agricultural chemicals, not elsewhere classified (SIC 2879).

Data on other SIC codes are being developed by the EPA/OSW and could be added in the future. Information in the ISDB was gathered from detailed questionnaires completed by industry, engineering analyses, and a waste sampling/analysis program. The data base contains detailed information on specific TSDF sites. Because of the confidential nature of much of the data, waste information was provided in a nonconfidential form to allow its use; e.g., generic chemical constituent names such as "amino alkane" were used where specific constituents were declared confidential.

D.2.2.5.1 Use of the ISDB. The WCDB contains ISDB waste composition data. The WCDB uses the ISDB SIC code, waste code, and its physical/chemical waste form to track and identify waste stream compositions. It then

uses the waste form's quantity in the ISDB to normalize constituent concentrations across multiple occurrences of the same waste stream. The SAM uses the ISDB composition data via the WCDB for TSDF with those SIC codes listed in the previous subsection. The SAM uses the following ISDB waste composition data:

- Constituents--The ISDB provides chemical constituents contained in an SIC code's waste code/waste form combination, i.e., a waste stream. The stream data have been compiled in a way that makes all information nonconfidential.

- Normalized constituent concentrations--Weighted average constituent concentrations were calculated for each of the constituents to yield a normalized waste stream composition. Normalizing sets all total constituent concentrations to 100 percent.

D.2.2.5.2 ISDB limitations. The ISDB used in the WCDB provided useful waste composition data not only for direct use in the SAM but also to fill data gaps in the WCDB, e.g., to create default compositions for SIC codes where waste compositions were not available. However, it is necessary to identify some limitations of the ISDB:

- The petroleum refining industry--one of the top five industry generators--was not available for the ISDB version used. The EPA/OSW surveyed this industry (SIC code 2911), but questionnaire responses were not accessible from the data base at the time. However, some raw field data were provided for the industry under the ISDB program. This is discussed in Section D.2.2.6. For waste streams with no field data, K stream data and default compositions were used.

- The ISDB used a larger number of more specific waste forms than the WCDB. To make the data more consistent with the WCDB, it was necessary to condense the ISDB list of waste forms to the six WCDB forms listed in Section D.2.2.4.1. This task was straightforward with most categories.

- The ISDB contains confidential business information. To use the ISDB waste characterization, its confidential data had to be made nonconfidential beforehand. As a result, the printout frequently did not identify RCRA D, K, P, and U waste codes. For example, instead of printing "K054," ISDB used "KXXX." It was possible to determine that DXXX represented D004 to D017 because ISDB did list D001, D002, and D003. However, the large number of K, P, and U waste codes

would not permit use of protected ISDB KXXX, PXXX, and UXXX compositional data as used for DXXX. Thus, this led to an increased use of default compositions by the SAM.

- The percent composition of waste stream constituents was sometimes listed as "unknown." In these cases, their concentrations were designated as zero because the other constituents with known concentrations typically added up to nearly 100 percent. This was considered to have a minimal impact on the SAM results.

- The number of participants in the ISDB program was small. However, the ISDB was considered the most thorough and accurate of the five data base sources and therefore was used in many respects such as in the development of D code default compositions.

- The waste constituents were often nonspecific, i.e., the ISDB listed constituents as generic chemicals such as "amino alkane." In these cases, a common chemical considered representative of the generic chemical was chosen so that the SAM could assign volatility and biodegradation classes to the constituent. Therefore, the presence of the generic chemical classes in the WCDB decreases the SAM's certainty of predicting appropriate emissions from that class.

D.2.2.6 New Field Test Data.

D.2.2.6.1 Data base description. This data base is a collection of waste composition data developed from the review of a hazardous waste TSDF process sampling report[28] and petroleum refining test data from the OSW listing program. It contains waste data from three industries:

- Petroleum refining (SIC 2911)

- Electroplating, plating, polishing, anodizing, and coloring (SIC 3471)

- Aircraft parts and auxiliary equipment, not elsewhere classified (SIC 3728).

This data base contains detailed information from specific TSDF sites.[29,30,31] The petroleum refining data were collected as part of the Industry Studies survey; however, they were not accessible through the ISDB.

D.2.2.6.2 Use of the data base. The WCDB contains this data file's waste compositions. It uses the file's SIC code, waste code, and waste

form to track and identify compositions. The data file contains the nine waste streams listed in Table D-6.

D.2.2.6.3 Data base limitations. The two sampling reports and the petroleum refining test data used to create the field data base did not always label waste stream information with RCRA waste codes. Therefore, it was necessary to assign waste codes and waste forms to stream compositions based on the reports' descriptions of sampling points and waste compositions. This may limit the certainty that the SAM uses the most representative waste compositions for waste codes.

The specific organic constituents for these nine streams were so numerous and so small in concentration that it was decided to reduce the chemicals to the following categories:

- Total paraffins
- Total aromatic hydrocarbons
- Total halogenated hydrocarbons
- Total oxygenated hydrocarbons
- Total unidentified hydrocarbons (includes oil)
- Total nonmethane hydrocarbons.

Some of these categories were already present in the TSDF chemical universe. Unidentified hydrocarbons proved to be the largest concentration category among waste streams because of their oil content.

D.2.2.7 Illinois EPA Data Base.

D.2.2.7.1 Data base description. Before an Illinois TSDF can accept RCRA wastes, they must obtain a permit from the Illinois EPA's Division of Land/Noise Pollution Control. For each waste, the applicant must detail its generation activities and provide analysis of each waste. The Illinois EPA has compiled this permit information in a data base. It contains waste compositions for RCRA hazardous and special nonhazardous waste streams from large quantity generators (>1,000 kg generated per month) in the State of Illinois and other States that ship wastes to Illinois TSDF for management. The data base used contained 35,000 permits.

TABLE D-6. WASTE STREAMS BY INDUSTRY IN THE FIELD TEST DATA[a]

SIC code	Industry	Waste code[b]	Waste form[c]
3471	Electroplating	D002	3XX[d]
3728	Aircraft Parts	D002	3XX[d]
2911	Petroleum Refining	D002	3XX[d]
2911	Petroleum Refining	D006	2XX
2911	Petroleum Refining	D007	2XX
2911	Petroleum Refining	K048	5XX
2911	Petroleum Refining	K049	5XX
2911	Petroleum Refining	K051	5XX
2911	Petroleum Refining	K052	2XX

SIC = Standard industrial classification.
WCDB = Waste Characterization Data Base.

[a]This table summarizes those waste streams compiled in a data base of field test results.[32,33] It reflects the industry tested and the waste code/form combinations tested and notes decisions made on how to use the data as part of the WCDB.

[b]Waste codes listed in 40 CFR 261, Identification and Listing of Hazardous Waste, Subpart C, Characteristics of Hazardous Waste, and Subpart D, Lists of Hazardous Wastes.[34]

[c]Physical/chemical waste forms are coded as follows:

1XX = Inorganic solid
2XX = Aqueous sludge
3XX = Aqueous liquid
4XX = Organic liquid
5XX = Organic sludge
6XX = Miscellaneous.

[d]The field data contained only a very small percentage of organic constituents; therefore, these organics were inserted into the existing WCDB compositions, normalizing the original[35] organics to maintain the original total organic percent composition.

D.2.2.7.2 Use of the data base. The Illinois EPA data used for this program contained the following information pertinent to the WCDB:

- Generator SIC code (most of the codes on file were assigned by the State)
- RCRA waste code(s)
- Physical phase of waste
- Waste composition (states whether the waste was organic or inorganic)
- Key waste stream constituents by name and percent composition.

A total of about 4,000 SIC code/waste code combinations were evaluated for incorporation into the WCDB. These 4,000 records reflect over 250 SIC codes.

D.2.2.7.3 Data base limitations. The Illinois EPA data expanded the volume and quality of information used in the WCDB. However, certain limitations were noted when the data were collected and organized:

- Only those permits listing RCRA waste codes were used in the WCDB. (This excluded the special nonhazardous wastes and hazardous waste permits with incomplete or no RCRA waste codes.) This ensures that only the most accurate waste data are used.
- Only Illinois waste permits listing just one RCRA code were incorporated into the WCDB. A large number of Illinois EPA permits contained more than one RCRA waste code. This decision decreased the usage of the Illinois EPA data, but those data used were considered higher in quality.
- Only those permits for which SIC codes could be identified were incorporated into the WCDB, for without SIC codes a waste composition cannot be properly assigned to its most appropriate generating industry. Most of the SIC codes found in the Illinois EPA data base were assigned by the State, not the waste permit applicant. All remaining records that were missing SIC codes were identified. A list of these records was printed by generator name. Dun and Bradstreet's 1986 Million Dollar Directory[36] was researched to identify as many generators by company name and SIC code as possible. However, it was not possible to identify all of the companies' codes. Only those permits for which SIC codes could be identified were incorporated into the WCDB.

D.2.2.8 RCRA K Waste Code Data Base.

D.2.2.8.1 Use of the data base. The original K waste code data base developed by Environ[37] describes these codes in terms of waste stream constituents, constituent concentrations, and other waste characteristics such as specific gravity and reactivity or ignitibility. The data base was derived from a combination of RCRA listing background documents, industry studies, and open literature. Thus, it generally provides a range of concentrations for any given constituent in a waste stream.

A representative concentration for each constituent in a waste stream was needed to develop waste stream characteristics and calculate emissions. Because the Environ data base reported varying compositions from various sources, Radian[38] selected representative constituent concentrations from the ranges provided in that data base. The WCDB uses this file of representative constituent concentrations for the SAM. For example, a mean would be used for a range of concentrations originating from one data source. However, if the waste data came from two or more sources, a more elaborate procedure was necessary to determine representative constituent information. For waste data from two sources, Radian chose the highest concentration of each constituent found in the two sources and then normalized the waste composition to 1,000,000 parts. This may have resulted in above-average concentrations of constituents; however, the approach was selected to ensure that at least a representative average concentration was identified. For waste with three or more data sources, a check was made for outlying values, and the remaining data were averaged to obtain representative constituent concentrations if no mean were provided.

D.2.2.8.2 K Stream data base limitations. Although this data base contained compositional information on each RCRA K stream, it had two limitations:

- Some stream compositions totaled less than 100 percent and were therefore incomplete. In such cases, the WCDB considered the unidentified components inorganic.

- Some waste constituents appeared as generic chemical constituents, e.g., "other chlorinated organics." Volatility and biodegradation classes were designated for those generic constituents by referencing a common chemical considered representative of that generic constituent.

D.2.2.9 WET Model Data Base.

D.2.2.9.1 Data base description. This data base contains 267 waste streams. Data collection for this data base concentrated on industry sectors where the impact of the RCRA land disposal regulations may be most significant. Based on the preliminary regulatory impact analysis (RIA) for the land disposal regulations,[39] those industry sectors potentially impacted to the greatest degree and included in this data base are:

- Wood preserving (SIC 2491)
- Alkalies and chlorine (SIC 2812)
- Inorganic pigments (SIC 2816)
- Synthetic organic fibers (SIC 2823, 2824)
- Gum and wood chemicals (SIC 2861)
- Organic chemicals (SIC 2865, 2869)
- Agricultural chemicals (SIC 2879)
- Explosives (SIC 2892)
- Petroleum (SIC 2911)
- Iron and steel (SIC 331, 332)
- Secondary nonferrous metals (SIC 3341)
- Copper drawing and rolling (SIC 3351)
- Plating and polishing (SIC 3471, 3479).

The WET Model study investigated the appropriate level of control for various hazardous wastes by characterizing a manageable number of waste streams, a process requiring a considerable amount of approximation and simplification. This process achieved two major objectives.

The approach to waste characterization was to develop a series of comprehensive profiles for each hazardous waste stream using available data. In many cases, these profiles were developed from partial information using processes of approximation and extrapolation.

D.2.2.9.2 Use of the data base. The WCDB uses the following WET data:

- SIC code
- RCRA waste code
- Phase description, i.e., composition in terms of oil, non-aqueous liquids, water, and solids content
- Constituent concentrations.

D.2.2.9.3 WET data base limitations. The quality of the available data varied greatly and, in general, was not as adequate for the WCDB as other data bases for several reasons. Among the reasons are the following:

- Nontoxic hazardous wastes are excluded from the data base because the model is capable of assessing only the toxicity hazard. Therefore, waste compositions exclude nontoxic, volatile organics.
- Waste compositions may total less than 100 percent because the data might have been incomplete for particular waste streams due to lack of available source material, either in absolute terms or in the time frame of this project. Thus, missing waste constituents were considered inorganic.
- Data availability also might have been limited for particular industries where there were few generators, e.g., in the pesticide industry.
- The data might have been imprecise in the recording of specific information, e.g., the reporting of total chromium with no quantitative information on the concentration of hexavalent chromium, which is by far the more toxic agent.[40]

Because of the variability in the data quality for constituent concentration, this data base was considered of lesser quality than others and, therefore, used less.

D.2.2.10 WCDB Waste Composition Defaults. As previously stated, the ISDB, WET, K stream, Illinois EPA, and field data bases were used primarily to provide waste stream constituents and their percent of the stream's composition. Although these data bases were extensive, they did not address each and every SIC code/waste code/form combination found in the Westat Survey data base. Therefore, default waste compositions were developed to fill these data gaps. This section explains how these default compositions were developed.

The existing ISDB D code compositions were used to develop default compositions for each combination of D001/waste form, D002/waste form, D003/waste form, and DXXX (i.e., D004-D017)/waste form. For example, if the ISDB had compositions of D001/4XX from four SIC codes, the four sets of compositions were composited to create one D001/4XX default composition. Each time the SAM finds a TSDF managing D001/4XX whose SIC code does not contain the waste stream in the existing data sources, the stream is assigned the default composition.

It was also necessary to develop default compositions for F code/waste form combinations not in the existing data bases. The distribution of constituents for each of the following F streams was derived from a background document[41] to the 40 CFR 261 regulations that provides consumption data on those chemicals found in RCRA waste codes F001 to F005.

For F001, halogenated degreasing solvents, the background document states that trichloroethylene is the solvent used most prevalently.[42] Unlike F002 to F005, there is no summary of F001 consumption by specific chemical solvent. Therefore, trichloroethylene serves as the solvent each time an F001 code appears in the TSDF data base.

The consumption data in the background document provided a percentage solvent distribution for waste codes F002 to F005, as shown in Table D-7.

Although a single waste code stream would not contain all of the chemicals listed, the distribution shown in Table D-7 allows one to address all chemicals in a manageable way.

Once the distribution of solvents among waste codes was completed, it was necessary to assign compositions by waste form, e.g.:

Waste form _XX Waste code F _ _ _ % Solvents _____ _% Solvent 1

_____ _% Solvent 2

_____ _% Solvent 3

_____ _% Solvent 4

For waste forms 1XX (inorganic solid) and 2XX (aqueous sludge), general wastewater engineering principles[45] were applied:

TABLE D-7. PERCENTAGE DISTRIBUTION FOR WASTE CODES F002 TO F005[a]

Solvent waste codes[b] and respective chemicals	Quantity of chemical consumed as solvent annually (ca. 1980), 10^3 Mg/yr	Percent consumption
F002/Tetrachloroethylene	255.8	26.6
Methylene chloride	213.2	22.2
Trichloroethene	188.2	19.6
Trichloroethane	181.4	18.9
Chlorobenzene	77.1	8.0
Trichlorotrifluoroethane	24.04	2.5
Dichlorobenzene	11.8	1.2
Trichlorofluoromethane	9.072	0.9
F003/Xylene	489.9	40.7
Methanol	317.5	26.3
Acetone	86.2	7.2
Methyl isobutyl ketone	78.0	6.5
Ethyl acetate	69.9	5.8
Ethanol	54.43	4.5
Ethyl ether	54.43	4.5
Butanol	45.36	3.8
Cyclohexanone	9.072	0.8
F004/Cresols	11.8	56.5
Nitrobenzene	9.072	43.5
F005/Toluene	317.5	51.5
Methyl ethyl ketone	202.3	32.8
Carbon disulfide	77.1	12.5
Isobutanol	18.6	3.0
Pyridine	0.907	0.2

[a]This table presents the annual usage of solvents in 1980.[43] The percent usage of each solvent with a waste code is estimated based on the 1980 data.

[b]Waste codes listed in 40 CFR 261.31, Hazardous wastes from non-specific sources.[44]

- Raw domestic wastewater is 0.07 percent solids.
- Digested domestic sludge is 10 percent solids.
- Vacuum-filtered sludge is 20 to 30 percent solids.

These principles were used, along with data from a RCRA land disposal restrictions background document,[46] which show that as much as 20 percent of the F codes in aqueous liquid (3XX) form are solvents. The same document was used to determine waste compositions for waste forms 4XX (organic liquid) and 5XX (organic sludge/solid). This document contains generic WET Model streams and their compositions for each of the three waste forms.

Table D-8 provides the default compositions developed for waste streams F001 to F005. In Table D-8, the waste stream constituent "water" may potentially contain oil.

Default compositions for all P and U code waste streams are designated 90-percent pure with 10 percent water when present in the natural physical/chemical form of the P and U chemical. A 90-percent purity is assumed given the nature of the regulatory listing, i.e., any commercial chemical product, manufacturing chemical intermediate, off-specification product, or intermediate (40 CFR 261.33).[49] This manner of listing implies how close to purity the waste chemical is.[50]

D.2.2.11 Organic Concentration Limits. During the development of the WCDB, it was found that respondents to the Westat Survey often listed RCRA waste codes as aqueous liquids and sludges when the codes themselves were described in 40 CFR 261 as organic by nature, e.g., F001--spent halogenated solvents and organic K, P, and U waste codes. These occurrences of aqueous listings indicated that the concentrated organic compositions commonly found in the WCDB were not representative of the waste code in a dilute aqueous form and could cause an overestimation of emissions. Also, in reviewing ISDB data for D waste codes, it was noted that the organic content of aqueous liquids and sludges was related to the type of management process (e.g., total organic concentrations for wastewaters managed in uncovered tanks and impoundments were typically lower than those managed in enclosed units such as underground injection wells). These issues led to the derivation of organic concentration limits for those wastes described above. These limits are presented in Table D-9.

TABLE D-8. DEFAULT STREAM COMPOSITIONS FOR WASTE CODES F001 TO F005[a]

Waste code[b]	Waste form[c]	Composition, % constituent
F001	1XX	15.00% Trichloroethylene 60.00% Water 25.00% Solids
	2XX	18.00% Trichloroethylene 72.00% Water 10.00% Solids
	3XX	20.00% Trichloroethylene 80.00% Water
	4XX	60.00% Trichloroethylene 40.00% Water
	5XX	20.00% Trichloroethylene 80.00% Solids
	6XX	NA
F002	1XX	60.00% Water 25.00% Solids 3.99% Tetrachloroethylene 3.33% Methylene chloride 2.94% Trichloroethylene 2.84% Trichloroethane 1.20% Chlorobenzene 0.38% Trichlorotrifluoroethane 0.18% Dichlorobenzene 0.14% Trichlorofluoromethane
	2XX	72.00% Water 10.00% Solids 4.79% Tetrachloroethylene 4.00% Methylene chloride 3.53% Trichloroethylene 3.40% Trichloroethane 1.44% Chlorobenzene 0.45% Trichlorotrifluoroethane 0.22% Dichlorobenzene 0.16% Trichlorofluoromethane

See notes at end of table.

(continued)

TABLE D-8 (continued)

Waste code[b]	Waste form[c]	Composition, % constituent
F002 (con.)		
	3XX	80.00% Water
		5.32% Tetrachloroethylene
		4.44% Methylene chloride
		3.92% Trichloroethylene
		3.78% Trichloroethane
		1.60% Chlorobenzene
		0.50% Trichlorotrifluoromethane
		0.24% Dichlorobenzene
		0.18% Trichlorofluoromethane
	4XX	40.00% Water
		16.00% Tetrachloroethylene
		13.30% Methylene chloride
		11.80% Trichloroethylene
		11.30% Trichloroethane
		4.80% Chlorobenzene
		1.50% Trichlorotrifluoromethane
		0.72% Dichlorobenzene
		0.54% Trichlorofluoromethane
	5XX	80.00% Solids
		5.32% Tetrachloroethylene
		4.44% Methylene chloride
		3.92% Trichloroethylene
		3.78% Trichloroethane
		1.60% Chlorobenzene
		0.50% Trichlorotrifluoromethane
		0.24% Dichlorobenzene
		0.18% Trichlorofluoromethane
	6XX	NA
F003	1XX	60.00% Water
		25.00% Solids
		6.10% Xylene
		3.94% Methanol
		1.08% Acetone
		0.98% Methyl isobutyl ketone
		0.87% Ethyl acetate
		0.68% Ethyl benzene
		0.68% Ethyl ether
		0.57% Butanol
		0.12% Cyclohexanone

See notes at end of table. (continued)

TABLE D-8 (continued)

Waste code[b]	Waste form[c]	Composition, % constituent
F003 (con.)		
	2XX	72.00% Water 10.00% Solids 7.33% Xylene 4.73% Methanol 1.30% Acetone 1.17% Methyl isobutyl ketone 1.04% Ethyl acetate 0.81% Ethyl benzene 0.81% Ethyl ether 0.68% Butanol 0.14% Cyclohexanone
	3XX	80.00% Water 8.14% Xylene 5.26% Methanol 1.44% Acetone 1.30% Methyl isobutyl ketone 1.16% Ethyl acetate 0.90% Ethyl benzene 0.90% Ethyl ether 0.76% Butanol 0.16% Cyclohexanone
	4XX	20.00% Water 32.60% Xylene 21.04% Methanol 5.76% Acetone 5.20% Methyl isobutyl ketone 4.64% Ethyl acetate 3.60% Ethyl benzene 3.60% Ethyl ether 3.04% Butanol 0.64% Cyclohexanone
	5XX	80.00% Solids 8.14% Xylene 5.26% Methanol 1.44% Acetone 1.30% Methyl isobutyl ketone 1.16% Ethyl acetate 0.90% Ethyl benzene 0.90% Ethyl ether 0.76% Butanol 0.16% Cyclohexanone
	6XX	NA

See notes at end of table.

(continued)

TABLE D-8 (continued)

Waste code[b]	Waste form[c]	Composition, % constituent
F004	1XX	60.00% Water 25.00% Solids 8.48% Cresols 6.52% Nitrobenzene
	2XX	72.00% Water 10.00% Solids 10.17% Cresols 7.83% Nitrobenzene
	3XX	80.00% Water 11.30% Cresols 8.70% Nitrobenzene
	4XX	20.00% Water 45.20% Cresols 34.80% Nitrobenzene
	5XX	80.00% Solids 11.30% Cresols 8.70% Nitrobenzene
	6XX	NA
F005	1XX	60.00% Water 25.00% Solids 7.72% Toluene 4.88% Methyl ethyl ketone 1.88% Carbon disulfide 0.45% Isobutanol 0.03% Pyridine
	2XX	72.00% Water 10.00% Solids 9.27% Toluene 5.90% Methyl ethyl ketone 2.25% Carbon disulfide 0.54% Isobutanol 0.04% Pyridine
	3XX	80.00% Water 10.30% Toluene 6.56% Methyl ethyl ketone 2.50% Carbon disulfide 0.60% Isobutanol 0.16% Pyridine

See notes at end of table. (continued)

TABLE D-8 (continued)

Waste code[b]	Waste form[c]	Composition, % constituent
F005 (con.)		
	4XX	20.00% Water 41.20% Toluene 26.20% Methyl ethyl ketone 10.00% Carbon disulfide 2.40% Isobutanol 0.16% Pyridine
	5XX	80.00% Solids 10.30% Toluene 6.56% Methyl ethyl ketone 2.50% Carbon disulfide 0.60% Isobutanol 0.16% Pyridine
	6XX	NA

NA = Not applicable.

[a]This table presents default waste stream compositions derived from WET model waste stream data[47] for wastewaters containing solvents and for organic liquids containing solvents. These defaults are used by the Source Assessment Model when Standard Industrial Classification code/waste code/waste form combinations are not found elsewhere in the Waste Characterizaton Data Base.

[b]Waste codes listed in 40 CFR 261.31, Hazardous wastes from non-specific sources.[48]

[c]Physical/chemical waste forms are coded as follows:

1XX = Inorganic solid
2XX = Aqueous sludge
3XX = Aqueous liquid
4XX = Organic liquid
5XX = Organic sludge
6XX = Miscellaneous.

TABLE D-9. CONCENTRATION LIMITS ASSUMED IN SOURCE ASSESSMENT MODEL (SAM) FOR ORGANIC CONCENTRATIONS IN WASTEWATERS AND AQUEOUS SLUDGES[a]

Waste code[b]	Organic concentration limit, %	
	Wastewaters (waste form 3XX)	Aqueous sludges (waste form 2XX)
P _ _ _[c]	1%	1%
U _ _ _[c]	1%	1%
F001-F005	1%[d]	1%[c]
K _ _ _[c,e]	1%	1%
D001[c,f]	5%	5%
D002[f]	0.4%[g]	0.4%[c]
D003[f]	6%[c]	6%[g]
D004 and greater[c,f]	0.1%	0.1%

[a]This table shows the maximum concentration the SAM assumes for organics when estimating emissions from wastewaters and aqueous sludges. These assumptions are conditional as described in the footnotes below and in Section D.2.2.11.

[b]Waste codes listed in 40 CFR 261, Identification and Listing of Hazardous Waste, Subpart C, Characteristics of Hazardous Waste, and Subpart D, Lists of Hazardous Wastes.[51]

[c]Source: Best engineering judgment based on review of waste code descriptions. (Nonconfidential Industry Studies Data Base data are inadequate or do not exist.)

[d]Source: Land disposal restrictions regulatory impact analysis.[52]

[e]Concentration limits apply only to K waste codes that are organic by nature of their listing, e.g, organic still bottoms and organic liquids. These limits do not apply to K waste codes that are listed as inorganic solids or aqueous sludges or liquids in 40 CFR 261.32.[53]

[f]Concentration limits apply only to aqueous liquids and sludges of RCRA D waste codes managed in open units, i.e., storage, treatment, and disposal impoundments and open treatment tanks.

[g]Source: EPA data analysis of nonconfidential Industry Studies Data Base data.

Sections D.2.2.11.1 through D.2.2.11.4 discuss these limits on organic content.

D.2.2.11.1 F001 to F005 (spent solvent). During the development of the proposed land disposal restriction rules for solvents and dioxins,[54] EPA/OSW analyzed waste composition data from a number of sources including the ISDB. The results of this analysis showed a median solvent concentration in wastewater (an aqueous liquid) of 0.05 percent and a mean of 0.3 percent.

The 1981 Westat Survey[55] identified greater than 99 percent of the solvent waste treated in surface impoundments as a wastewater form of the solvent. The land disposal restriction Regulatory Impact Analysis did not provide a typical waste composition of solvents in these wastewaters; however, it did state that solvent constituent concentrations in F001 to F005 wastes may be "as little as one percent or less (if present at all)."[56] For these reasons, a limit of 1 percent was set on solvents found in wastewater. The 1-percent limit was also assigned to aqueous sludges.

D.2.2.11.2 Organic P, U, and K wastes. It was also decided to assign 1-percent organic concentration limits to aqueous liquids and sludges of organic P, U, and K wastes because of the decisionmaking used for solvents F001 to F005. Given that these P, U, and concentrated organic K wastes are just as concentrated as solvent wastes (based on their normal listing as organic liquids or sludges), their dilution to 1 percent or less in wastewater or aqueous sludges should be comparable to the solvents in F001 to F005. Many of these organics also may be insoluble in water and are decanted from the wastewater before it enters the open management unit. Therefore, a 1-percent organic concentration limit was assigned to these waste codes when they occur as wastewaters or aqueous sludges.

D.2.2.11.3 D001. This limit reflects the minimum concentration of an ignitible organic in water that causes the water to exhibit an ignitible characteristic. Based on engineering judgment, the organic concentration limit designated for D001 is 5 percent. For example, an ignitible organic liquid (about 100 percent organic) has a heat value of about 30,000 J/g; an aqueous liquid containing 10 percent ignitible organic may have a heat

value of 3,000 J/g and thus still be burnable; however, an aqueous liquid with 1 percent ignitible organic will not be ignitible because the heat value is 300 J/g. As another example, ignitible methanol can have a concentration in water between 2 and 10 percent and the water remains ignitible. Less than 1 percent would not be ignitible. This range of 1 to 10 percent was used to arrive at an average minimum concentration of an ignitible organic in wastewater that yields an ignitible aqueous liquid, i.e., 5 percent.

D.2.2.11.4 D002, D003, and D004 to D017 (DXXX). Concentration limits were established for these waste codes using the ISDB. The ISDB was searched to identify D002, D003, and D004 to D017 waste codes that were either aqueous liquids (wastewaters) or sludges and were managed in storage surface impoundments, onsite wastewater impoundments, or onsite wastewater tanks. Each of these management devices was considered open to the atmosphere. Once these waste compositions were found, a weighted average was taken for each waste code managed in these open units based on quantity managed for each waste code/waste form combination. These weighted averages serve as organic concentration limits for the open waste management units.

D.2.3 Chemical Properties

D.2.3.1 Introduction. Emission estimation on a constituent basis for each of the more than 4,000 TSDF waste constituents identified in the data bases was not possible because of a lack of constituent-specific data and because of the large number of chemicals involved. Therefore, to provide the emission models with relevant physical, chemical, and biological properties that influence emissions and still maintain a workable and efficient method of estimating emissions, waste constituent categorization was required. Waste constituent categorization allows the SAM to make emission estimates for all constituents by making emission estimates for a set of chemicals (surrogates) that represent the universe of organic chemicals that occur in hazardous waste streams.

D.2.3.2 Waste Characteristics Affecting Emissions. In the development of air emission models for hazardous waste TSDF, the means by which organic compounds escape to the environment from TSDF was determined. It

was found that the fate of organic compounds in surface impoundments, land treatment facilities, landfills, wastepiles, or wastewater treatment (WWT) plant effluents can be affected by a variety of pathway mechanisms, including volatilization, biological decomposition, adsorption, photochemical reaction, and hydrolysis. The relative importance of these pathways for TSDF waste management processes was evaluated based on theoretical considerations, data appearing in the literature, and engineering judgment. The predominant removal pathways for organic compounds at TSDF sites were found to be volatilization and biodegradation. For this reason, the emission models used for TSDF in the air emission models report[57] are all based on volatilization and/or biodegradation as the principal pathways included in the models. Volatilization occurs when molecules of a liquid or solid substance escape to an adjacent gas phase. Biodegradation takes place when microbes break down organic compounds for metabolic processes.

Several waste characteristics contribute to the potential for a waste constituent to be volatilized or released to the atmosphere. Major factors include the types and number of hazardous constituents present, the concentrations of these constituents in the waste, and the chemical and physical characteristics of the waste and its constituents. In conjunction with the type of management unit, the physical and chemical properties of the waste constituents will affect whether there will be pollutants released and what form the release will take (i.e., vapor, particulate, or particulate-associated). Important physical/chemical factors to consider when assessing the volatilization of a waste constituent include:

- Water solubility. The solubility in water indicates the maximum concentration at which a constituent can dissolve in water at a given temperature. This value can be used to estimate the distribution of a constituent between the dissolved aqueous phase in the unit and the undissolved solid or immiscible liquid phase. Considered in combination with the constituent's vapor pressure, solubility can provide a relative assessment of the potential for volatilization of a constituent from an aqueous environment.

- Vapor pressure. This property is a measure of the pressure of vapor in equilibrium with a pure liquid. It is best used in a relative sense as a broad indicator of volatility; constituents with high vapor pressures are more likely to be released than are those with low vapor pressures, depending on other factors

such as relative solubility and concentration (e.g., at high concentrations, release can occur even though a constituent's vapor pressure is relatively low).

- Octanol/water partition coefficient. The octanol/water partition coefficient indicates the tendency of an organic constituent to absorb to organic components of soil or waste matrices. Constituents with high octanol/water partition coefficients tend to adsorb readily to organic carbon, rather than volatilize to the atmosphere. This is particularly important in landfills and land treatment units, where high organic carbon content in soils or cover material can significantly reduce the release potential of volatile constituents.

- Partial pressure. A partial pressure measures the pressure that each component of a mixture of liquid or solid substances will exert to enter the gaseous phase. The rate of volatilization of an organic chemical when either dissolved in water or present in a solid mixture is characterized by the partial pressure of that chemical. In general, the greater the partial pressure, the greater the potential for release. Partial pressure values are unique for any given chemical in any given mixture and may be difficult to obtain.

- Henry's law constant. Henry's law constant is the ratio of the vapor pressure of a constituent to its aqueous solubility (at equilibrium). This constant can be used to assess the relative ease with which the compound may vaporize from the aqueous phase. It is applicable for low concentration (i.e., less than 10 percent) wastes in aqueous solution and will be most useful when the unit being assessed is a surface impoundment or tank containing dilute wastewaters. The potential for significant vaporization increases as the value for Henry's law constant increases.

- Raoult's law. Raoult's law accurately predicts the behavior of most concentrated mixtures of water and organic solvents (i.e., solutions over 10 percent solute). According to Raoult's law, the rate of volatilization of each chemical in a mixture is proportional to the product of its concentration in the mixture and its vapor pressure. Therefore, Raoult's law can also be used to characterize volatilization potential.

The air emission models report provides the most up-to-date guidance on assessing the volatilization of waste constituents and contains a compilation of chemical/physical properties for several hundred constituents.

Through review of available literature relating to TSDF emission modeling, it was judged that volatility, which is an index of emission potential, can best be characterized across the entire waste population by

either vapor pressure or Henry's law constant depending on the waste matrix. One case accounts for chemical compounds in situations in which Henry's law governs mass transfer from the waste (i.e., low organic concentration in aqueous solution), and the other case accounts for chemical compounds in those situations in which mass transfer is governed by vapor pressure (i.e., concentrated mixtures of organics).

Three chemical and biological properties are therefore critical in estimating TSDF emissions: vapor pressure, Henry's law constant, and biodegradation rate. These were selected as the basis for designating waste constituent and surrogate categories.

D.2.3.3 Waste and Surrogate Categorization.

D.2.3.3.1 Waste properties--physical and chemical. Efforts to categorize the universe of chemical compounds found at hazardous waste sites were based on information contained in the CHEMDAT3 data base.[58] The 60 chemicals and their properties available from this data base, originally used in predicting organic emissions, formed the basis for both waste constituent categorization and surrogate properties selection. Table D-10 provides the primary data for the 60 chemicals used in developing surrogate categories and properties.

D.2.3.3.1.1 Vapor pressure categories. In 1985, EPA published a comprehensive catalog of physical and chemical properties of hazardous waste in relation to potential air emissions of wastes from TSDF. The waste volatility categorization scheme presented in the document[59] divided vapor pressures into three useful categories: high (>1.33 kilopascals [kPa]), moderate (1.33×10^{-4} to 1.33 kPa), and low ($<1.33 \times 10^{-4}$ kPa). Sensitivity analysis on the impact of vapor pressure on emissions pointed out that organics that are gases at standard temperature and pressure skewed the average emission rates for the high vapor pressure chemicals. Emission estimates for high vapor pressure chemicals were dominated by the gases; an average figure would overestimate emissions for most high vapor pressure chemicals because gases are relatively few in number among the high category chemicals. Therefore, compounds with vapor pressures greater than 101.06 kPa were segregated into their own "very high" category, creating four categories of vapor pressure chemicals. Vapor pressures for

TABLE D-10. DATA USED FOR WASTE CONSTITUENT CATEGORIZATION AND SURROGATE PROPERTY SELECTION IN THE SOURCE ASSESSMENT MODEL[a,b]

Compound name	Vapor pressure, kPa	Henry's law constant, 10^{-3} kPa•m^3/g mol	Biorate, mg VO/g/h	Biodegradability category	Surrogate category[c]	
					Vapor pressure	Henry's law constant
Acetaldehyde	122	9.6	82.4	High	10	4
Methyl ethyl ketone	13.3	4.4	73.8	High	1	4
Toluene	3.99	675	73.5	High	1	1
Acrylonitrile	15.2	8.9	44.30	High	1	4
Pyridine	2.02	2.4	35.03	High	1	4
Phenol	0.045	0.0459	33.6	High	4	7
Butanol-1	0.864	0.9	32.4	High	4	7
Dichloroethane (1,2)	10.6	6.4	0.302	Low	3	3
Formaldehyde	465	5.8	20.91	High	10	4
Cresol (-m)	0.01	0.3	23.2	High	4	7
Cresol (-p)	0.015	0.3	23.2	High	4	7
Cresols	0.019	0.3	23.2	High	4	7
Cresol (-o)	0.032	0.3	22.8	High	4	7
Methylene chloride	58.2	322	22.00	High	1	1
Isobutyl alcohol	1.33	0.2	21.2	High	4	7
Methyl acetate	31.2	NA	19.9	High	1	1
Benzene	12.7	556	19.00	High	1	1
Benzyl chloride	0.0093	52.7	17.8	High	4	4
Ethyl acetate	11.3	12.9	17.6	High	1	4
Cresylic acid	0.04	0.2	15.00	High	4	7

See notes at end of table.

(continued)

TABLE D-10 (continued)

Compound name	Vapor pressure, kPa	Henry's law constant, 10^{-3} kPa•m^3/g mol	Biorate, mg VO/g/h	Biodegradability category	Surrogate category[c] Vapor pressure	Surrogate category[c] Henry's law constant
Acetone	35.4	2.5	14.6	High	1	4
Methanol	15.2	0.3	12.00	High	1	7
Cyclohexanone	0.64	0.4	11.5	High	4	7
Dichlorobenzene (1,2) (-o)	0.2	196	10.00	High	4	1
Acrolein	32.5	5.7	7.80	Moderate	2	5
Nitrobenzene	0.04	1.3	0.302	Low	6	6
Maleic anhydride	1.33×10^{-5}	0.004	4.08	Moderate	8	8
Chloroform	27.7	3.42	0.302	Low	3	3
Chlorobenzene	1.57	397	1.46	Moderate	2	2
Ethylether	69.1	68.7	0.77	Low	3	6
Methyl isobutyl ketone	0.997	4.4	0.74	Low	6	6
Allyl alcohol	3.098	NA	NA	Moderate	2	8
Carbon disulfide	48.7	1,212	NA	Moderate	2	2
Carbon tetrachloride	15.03	3,030	NA	Low	3	3
Chloroprene	36.3	NA	NA	Low	3	NA
Cumene (isopropylbenzene)	0.612	1,480	NA	Moderate	5	2
Dichlorobenzene (1,4) (-p)	0.16	162	NA	Moderate	5	2
Dimethyl nitrosamine	NA	NA	NA	Moderate	NA	NA
Dioxin	NA	NA	NA	Low	NA	NA
Epichlorohydrin	2.26	3.3	NA	Low	3	6
Ethylbenzene	1.33	650	NA	High	4	1

See notes at end of table.

(continued)

TABLE D-10 (continued)

Compound name	Vapor pressure, kPa	Henry's law constant, 10^{-3} kPa•m^3/g mol	Biorate, mg VO/g/h	Biodegradability category	Surrogate category[c] Vapor pressure	Surrogate category[c] Henry's law constant
Ethylene oxide	166	3.7	NA	High	10	4
Freons	NA	NA	NA	Low	NA	NA
Hexachlorobutadiene	0.02	2,590	NA	Low	6	3
Hexachlorocyclopentadiene	0.0108	1,620	NA	Low	6	3
Naphthalene	0.031	119	NA	Moderate	5	2
Nitrosomorpholine	NA	NA	NA	Low	NA	NA
Phosgene	185	17,300	NA	Low	12	3
Phthalic anhydride	0.0002	0.1	NA	High	4	7
Polychlorinated biphenyls	NA	20.2	NA	Low	NA	NA
Proplyene oxide	59.2	19.4	NA	High	1	4
Tetrachloroethane (1,1,2,2)	0.864	38.4	NA	Low	6	6
Tetrachloroethylene	2.53	NA	NA	Low	3	3
Trichloro (1,1,2) trifluoroethane		119	NA	Low	3	3
Trichloroethane (1,1,1)	16.4	8,081	NA	Low	3	3
Trichloroethylene	9.97	919	NA	Low	3	3
Trichlorofluoromethane	105.8	5,890	NA	Low	12	3
Vinyl chloride	354	8,690	NA	Low	12	3
Vinylidene chloride	78.6	19,200	NA	Low	3	3
Xylene (-o)	0.931	618	NA	High	4	1

NA = Not available.
VO = Volatile organics.

[a]This table provides the primary data for 60 chemicals used in developing surrogate categories to be used in the Source Assessment Model.

[b]Source of data: Research Triangle Institute. CHEMDAT3 Database for Predicting VO Emissions from Hazardous Waste Facilities. Developed for Office of Research and Development, U.S. Environmental Protection Agency. Cincinnati, OH. 1986.[58]

[c]Refers to surrogate categories defined in Table D-11.

the 60 reference chemicals were obtained from or estimated using methods commonly found in engineering and environmental science handbooks.[60,61,62]

D.2.3.3.1.2 Henry's law categories. The Henry's law constant is a measure of the diffusion of organics into air relative to diffusion through liquids. Henry's law constants are generated using vapor pressure, molecular weight, and solubility. Henry's law is used in predicting emissions for aqueous systems. An analysis to determine the effects of Henry's law constant on the organic fraction emitted to air, using the TSDF air emission models, was used in establishing Henry's law constant categories. Results showed discernible patterns in the relationship between the organic fraction emitted and Henry's law constant. The fraction emitted begins to drop sharply for low values of Henry's law constant ($<10^{-3}$ kPa m^3/g mol) as the mass transfer becomes affected by both gas and liquid phase control. When Henry's law constant is greater than 10^{-1} kPa m^3/g mol, rapid volatilization will generally occur. A number of citations found in the literature support the Henry's law constant volatilization categories selected.[63,64] Henry's law constants were grouped as follows:

- High $>10^{-1}$, kPa m^3/g mol
- Moderate 10^{-1} to 10^{-3}, kPa m^3/g mol
- Low $<10^{-3}$, kPa m^3/g mol.

D.2.3.3.1.3 Biodegradation categories. Quantitative biodegradation values for the 60 chemicals were grouped as follows: high = >10 mg organics/g of biomass/h, moderate = 1 to 10 mg organics/g/h, and low = <1 mg organics/g/h. This classification follows the biorate designation provided with the data base on the 60 chemicals.[65] In some cases, the biodegradation rate was inconsistent with values reported elsewhere for measures such as BOD_5, soil half-life, and ground-water degradation. It is understood that biodegradability is variable and depends on the matrix, the concentration of organics and microorganisms, and temperature. However, to provide an "average" biorate that represents all TSDF management processes, biodegradation rates provided for many of the 60 chemicals were compared to other measures of biodegradation and adjusted if appropriate.

D.2.3.3.2 Surrogate categories. With 4 categories of vapor pressure, 3 of Henry's law constant, and 3 of biodegradation, a chemical could fall into one of 12 possible categories of vapor pressure and biodegradation (4 x 3) and into one of 9 categories of Henry's law constant and biodegradation. These two surrogate groups (i.e., vapor pressure surrogates and Henry's law surrogates) represent two volatility situations: where vapor pressure is the mass transfer driving force in one case and where Henry's law constant best represents or governs mass transfer in the other. Table D-11 provides the definition of surrogate categories.

D.2.3.3.3 Surrogate properties--physical and chemical. The chemical and biological properties selected to represent each surrogate are, generally, averages for groupings of the 60 chemicals categorized by vapor pressure/biodegradation and Henry's law constant/biodegradation. It should be noted that not all of the possible categories of vapor pressure/biodegradation and Henry's law constant/biodegradation were unique. The low vapor pressure categories were judged to be relatively equivalent; therefore, the low vapor pressure/moderate biorate (LVMB) properties were used for all low vapor pressure compounds. The low Henry's law constant/low biorate (LHLB) category was judged to be very similar to the low Henry's law constant/moderate biorate (LHMB) category. The high vapor pressure/moderate biorate (HVMB) and the high vapor pressure/low biorate (HVLB) were also found to be similar in predicting emissions. Property values for all surrogate categories are therefore not presented. Tables D-12 and D-13 summarize the surrogate properties for the vapor pressure and the Henry's law constant groupings, respectively.[66]

Emissions for waste management processes that are modeled using vapor pressure draw their surrogate properties from vapor pressure and biodegradation group averages. Similarly, processes best modeled by Henry's law constant draw surrogate properties from the groupings of Henry's law constant and biodegradation. This is because the SAM, as designed, handles only a single set of emission factors for each waste management unit; for example, only Henry's law constant surrogates are used to calculate emissions for surface impoundment operations because emissions from surface impoundment wastes are predominantly Henry's law controlled and because

TABLE D-11. DEFINITION OF WASTE CONSTITUENT CATEGORIES (SURROGATES) APPLIED IN THE SOURCE ASSESSMENT MODEL[a]

	Surrogate category	Constituent properties		
		VP[b]	HLC[c]	Bio[d]
Vapor Pressure Surrogates	1	H	NA	H
	2	H	NA	M
	3	H	NA	L
	4	M	NA	H
	5	M	NA	M
	6	M	NA	L
	7	L	NA	H
	8	L	NA	M
	9	L	NA	L
	10	VH	NA	H
	11	VH	NA	M
	12	VH	NA	L
Henry's Law Constant Surrogates	1	NA	H	H
	2	NA	H	M
	3	NA	H	L
	4	NA	M	H
	5	NA	M	M
	6	NA	M	L
	7	NA	L	H
	8	NA	L	M
	9	NA	L	L

NA = Not applicable.

[a]This table describes the volatility and biodegradation properties of each waste constituent (surrogate) category developed for use in the Source Assessment Model.

[b]VP = Vapor pressure categories:

VH = Very high (>101.06 kPa).
H = High (1.33-101.06 kPa).
M = Moderate (1.33×10^{-4}-1.33 kPa).
L = Low (<1.33×10^{-4} kPa).

[c]HLC = Henry's law constants.

H = High (>10^{-1} kPa m^3/g mol).
M = Moderate (10^{-1}-10^{-3} kPa m^3/g mol).
L = Low (<10^{-3} kPa m^3/g mol).

[d]Bio = Biodegradation rates:

H = High (>10 mg VO/g biomass/h).
M = Moderate (1-10 mg VO/g biomass/h).
L = Low (<1 mg VO/g biomass/h).

TABLE D-12. PROPERTIES FOR VAPOR PRESSURE AND BIODEGRADATION GROUPINGS[a] AT 25 °C OF WASTE CONSTITUENT CATEGORIES (SURROGATES) SHOWN IN TABLE D-11

Surrogate category[b]	M.W.	Vapor pressure at 25 °C kPa (10^{-3})	Diffusivity in water, cm^2/s (10^{-6})	Diffusivity in air, cm^2/s (10^{-3})	Biorate, mg VO/g/h
HVHB (1)	73.6	27.4	10.6	98.9	34.30
HVMB (2)	72.5	24.2	10.7	134	5.97
HVLB (3)	117.0	34	9.63	89.9	0.30
MVHB (4)	111.0	0.346	9.02	76.8	22.60
MVMB (5)	132.0	0.266	7.50	64.3	3.02
MVLB (6)	185.0	0.386	7.32	66.9	0.39
LVMB (8)	98.0	1.33×10^{-5}	11.1	95	4.08
VHVHB (10)	39.3	251	14.6	101	47.50
VHVLB (12)	80.7	270	11.8	107	0.30

M.W. = Molecular weight.
VO = Volatile organics.
HVHB = High vapor pressure, high biorate.
HVMB = High vapor pressure, moderate biorate.
HVLB = High vapor pressure, low biorate.
MVHB = Moderate vapor pressure, high biorate.
MVMB = Moderate vapor pressure, moderate biorate.
MVLB = Moderate vapor pressure, low biorate.
LVMB = Low vapor pressure, moderate biorate.
VHVHB = Very high vapor pressure, high biorate.
VHVLB = Very high vapor pressure, low biorate.

[a]Properties presented in this table are averages for compounds found within a given category. A detailed discussion on the development of this table can be found in a memorandum to the docket.[67]

[b]Not all of the 12 possible categories were unique. The low vapor pressure categories (LVHB, LVMB, and LVLB) were judged to be relatively equivalent. Therefore, the LVMB group properties were used for all low vapor pressure compounds. The moderate and low biorate categories for the very high vapor pressure group were also shown to result in similar emissions; therefore, the VHVLB group properties were used for both categories.

TABLE D-13. PROPERTIES FOR HENRY'S LAW CONSTANT AND BIODEGRADATION GROUPINGS OF WASTE CONSTITUENT CATEGORIES (SURROGATES) SHOWN IN TABLE D-11[a]

Surrogate category	M.W.	Diff. water, cm^2/s (10^{-6})	Diff. air, cm^2/s (10^{-3})	Biorate, mg VO/g/h	X_{VOC} (10^{-3})	Temperature adjustment equation[b]	H-law const. 298 K[c] (10^{-6})
MHLB (6)	112.0	8.60	76.4	0.39	3.27	$H = e^{[(-4879.12/T) + 17.1726]}/990$	22.5
HHLB (3)	144.0	9.39	87.6	0.302	2.54	$H = e^{[(-2275.36/T) + 15.6418]}/990$	3,030
LHMB (8)	78.4	11.3	180	3.55	4.66	$H = e^{[(-11562.27/T) + 23.14]}/.0099$	0.160
MHMB (5)	57.0	11.8	115	11.2	6.40	$H = e^{[(-4090.15/T) + 15.13143]}/990$	41.2
HHMB (2)	117.0	8.24	74	2.71	3.13	$H = e^{[(-5462.87/T) + 23.10247]}/990$	1,190
LHHB (7)	97.3	9.64	82.7	23.2	3.76	$H = e^{[(-11562.27/T) + 23.14]}/.0099$	0.160
MHHB (4)	69.9	11.6	95.6	40.1	5.23	$H = e^{[(-3256.36/T) + 12.84471]}/990$	68.7
HHHB (1)	98.4	9.40	87.3	29.2	3.72	$H = e^{[(-3180.14/T) + 16.95871]}/990$	5,430

X = Mole fraction of volatile organic compounds (VOC).
VO = Volatile organics.
Diff. = Diffusivity.
M.W. = Molecular weight.
MHLB = Moderate Henry's law constant, low biorate.
HHLB = High Henry's law constant, low biorate.
LHMB = Low Henry's law constant, moderate biorate.
MHMB = Moderate Henry's law constant, moderate biorate.
HHMB = High Henry's law constant, moderate biorate.
LHHB = Low Henry's law constant, high biorate.
MHHB = Moderate Henry's law constant, high biorate.
HHHB = High Henry's law constant, high biorate.

Note: (1) The low Henry's law constant--low biorate category is not provided because it was judged to be very similar to the LHMB category in predicting emissions.
(2) The weight fraction of the surrogate (g surrogate/g waste), Wi/W, was assumed to be 2.00×10^{-2} for all surrogate categories.

[a]This table presents average properties for compounds found in a given surrogate category. A detailed discussion on the development of this table can be found in a memorandum to the docket.[68]

[b]Henry's law constant units are Kpa • m^3/g mol. The equation predicts Henry's law constant for a range of temperatures for each category.

[c]Henry's law constants at 25 °C (298 K) are those used in emission models; see Appendix C.

dilute aqueous wastes are typically stored there. In the case of Henry's law constants, surrogate values were not based on group averages. For the surrogate's Henry's law constant, a single constituent was selected to represent the surrogate group; all other surrogate properties are averages of the group of constituents that fall into the particular surrogate category. This approach was selected in order to generate the temperature-dependent Henry's law constant equations needed for each surrogate category.

D.2.3.4 Assigning Surrogates. The TSDF Waste Characterization Data Base (see Section D.2.2) data sources often provided only generic descriptions of waste constituents, e.g., "amino alkane." Therefore, the first requirement in assigning a surrogate to the more than 4,000 constituent chemicals found in the WCDB was the assignment of specific common chemicals to represent the generic compounds. Next, all specific chemicals were assigned physical, chemical, and biodegradation values. Vapor pressures and Henry's law constants were estimated for 25 °C, if possible. Vapor pressure values were not available for a large fraction of the chemicals. Vapor pressure assignments were completed by relating molecular structure and molecular weight to similar chemicals with known vapor pressures. Specific solubility values, used to estimate Henry's law constants, were assigned as follows when qualitative descriptions were found in the literature:[69,70] insoluble--2 mg/L, practically insoluble--10 mg/L, slightly soluble--100 mg/L, soluble--2,000 mg/L, very soluble--10,000 mg/L, and miscible--100,000 mg/L. If no information was found in the references, solubility values were estimated based on molecular structure. The molecular weight of chemicals was readily available or determinable, although there was some judgment required in assigning molecular weight for polymers. Biodegradation assignments were based on quantitative measures, although largely unavailable, or on a comparison of molecular structure with chemicals well characterized by biodegradation.[71] The approximate breakdown of biodegradation information is shown in Table D-14.

The biorate values used for predicting emissions were based on the biodegradation rates for the "high" class of 60 chemicals. The average biodegradation for the high category is approximately 30 mg VO/g biomass/h.

TABLE D-14. CLASSIFICATION OF BIODEGRADATION DATA[a]

Parameter	Classification		
	High	Moderate	Low
BOD_5	>1.0	1.0 to 0.25	<0.25
Soil half-life	<3 days	3 days to 30 days	>30 days

BOD_5 = 5-day biochemical oxygen demand.

[a]This table provides classification of biodegradation data so that waste constituents may be categorized for the Source Assessment Model based on biodegradability.

A value of 1/10th the average of the "high" biorates was applied for those compounds judged to display "moderate" degradation, and a value equal to 1/100th of the average of the "high" biorates was applied for those compounds judged to display "low" biodegradation. The low and moderate biodegradation values (1/100 and 1/10 of "high," respectively) were consistent with group averages for the 60 chemicals.

Once the complement of properties for all chemicals was completed, then all chemicals were grouped into appropriate surrogate categories based on their vapor pressure, Henry's law constant, and biodegradation values.

D.2.4 Emission Factors

D.2.4.1 Introduction. A major objective of the SAM was to develop nationwide estimates of organic compound emissions to the atmosphere for the range of organic chemicals found at hazardous waste sites. Therefore, for each of the TSDF chemical surrogate categories selected to represent the organic chemicals that occur in hazardous waste streams, the emission models discussed in Appendix C and the air emission models report[72] were used to estimate organic losses to the atmosphere. Emissions were estimated for process losses and transfer and handling losses (i.e., spills, loading losses, and equipment leaks) for each type of TSDF management process. Loss of organics from the waste stream through biodegradation was also estimated for those management processes having associated biological activity.

An important point concerning the emission factors is that they are a function of chemical surrogate properties, air emission models, and TSDF

model unit parameters. For each chemical constituent, the assigned surrogate's chemical, physical, and biological properties are used in determining the fraction of incoming organics that are emitted or biodegraded. Other input parameters to the emission models are provided by the TSDF model units discussed in Appendix C. Once a surrogate is chosen, the TSDF model unit selected, and the emission model determined, values for emission factors can be estimated.

D.2.4.2 Emission Models. The emission factors used for estimating TSDF emissions in this document were calculated using the TSDF air emission models as presented in the March 1987 draft of the Hazardous Waste Treatment, Storage, and Disposal Facilities: Air Emission Models, Draft Report. Since that time, certain TSDF emission models have been revised and a new edition of the air emission models report was released (December 1987). The principal changes to the emission models involved refining the biodegradation component of the models to more accurately reflect biologically active systems handling low organic concentration waste streams. With regard to emission model outputs, the changes from the March 1987 draft to the December 1987 version affected, for the most part, only aerated surface impoundments and result in a minor increase in the fraction emitted for the chemical surrogates in the high biodegradation categories. For the other air emission models, such as the land treatment model, which were also revised to incorporate new biodegradation rate data, the changes did not result in appreciable differences in the emission estimates. Since the December 1987 report version was issued, new data on biodegradation rates have been obtained and comments were received.[73] Based on these data and comments, the biodegradation model for aerated wastewater treatment systems was further revised to incorporate Monod kinetics. Additional investigation and comments led to an evaluation of changes to the model units used for aerated tanks and impoundments and assumed surrogate concentrations. These changes improve the technical basis for the biodegradation model. However, the combined effect of these changes did not significantly affect the estimated nationwide emissions and other impacts presented in this document.[74] Therefore, the emission factors listed in this appendix remain based on the March 1987 draft of the air emission model report, the model unit definitions have not been changed, and the assumed surrogate concentrations have not been changed.

These models represent long-term steady-state emissions for land treatment, first-year emissions for landfills, and emissions consistent with residence times identified for the model units in Appendix C for wastepiles, surface impoundments, containers, and tanks. Inputs to the models are those that are determined to best predict average, long-term emission characteristics rather than short-term peak concentrations. Long-term emissions are judged to be more representative of actual TSDF emission patterns and best characterize those management process emissions that are potentially controlled. Long-term emission estimates (i.e., annual averages) are also required for impacts analysis; costs, cancer incidence, and ozone effects all are based on long-term emissions. Short-term emissions such as those resulting from application of waste to the soil surface in land treatment, as opposed to postapplication emissions, and therefore are not included in the emission estimates.

Input parameters differ for each emission model and include such variables as unit size, throughput, and retention time, all of which were selected to be as consistent and representative as possible across the management processes. A detailed breakdown of the model unit input parameters by management process is presented in Appendix C, Section C.2.

D.2.4.3 Emission Factor Files. To determine TSDF emission factors for use in the SAM, information on process type, design characteristics, and operating parameters was necessary. Within each waste management process represented by a process code (e.g., S01, S02, T01, or T02), there are in most cases distinct process types. For example, treatment tanks (T01) can be quiescent or aerated, and quiescent tanks can be either covered or uncovered. Table D-15 presents the distribution of waste management process types used in the SAM to characterize the breakdown of waste management processes on a nationwide basis.

For each waste management process type within a process code, multiple model units (described in Appendix C) were developed to span the range of nationwide design characteristics and operating parameters (i.e., surface area, waste throughputs, detention time, etc.). Because these particular characteristics were generally not available for site-specific estimates, it was necessary to develop a "national average model unit" to represent each waste management process or process type. This was accomplished by

TABLE D-15. NATIONWIDE DISTRIBUTION OF WASTE MANAGEMENT PROCESS TYPES USED IN THE SOURCE ASSESSMENT MODEL[a]

Process code	Process type	National distribution, %
Container storage (S01)	Drum storage	97
	Dumpsters	3
Tank storage (S02)	Covered storage	79
	Uncovered storage	21
Tank treatment (T01)	Quiescent covered treatment	30
	Quiescent uncovered treatment	20
	Aerated/agitated uncovered treatment	50
Surface impoundment treatment (T02)	Quiescent treatment	29
	Aerated/agitated treatment	71
Other treatment (T04)[b]	Quiescent covered treatment	100
Landfill disposal (D80)	Onsite active landfill	14
	Onsite closed landfill	55
	Offsite active landfill	6
	Offsite closed landfill	25
Land treatment (D81)	Surface application	93
	Subsurface application	7

[a]This table presents the estimated national distribution of waste management process types within a process code. Those process codes not listed are not subdivided within the process code.

[b]Other treatment is not subdivided, but is defined as a quiescent covered treatment tank for modeling purposes.

generating a set of weighting factors for each TSDF waste management process or process type based on frequency distributions of quantity processed, unit size, or unit area that were presented in results of the Westat Survey. Each set of weighting factors (presented in Appendix C, Section C.2) approximates a national distribution of the model units defined for a particular TSDF waste management process or process type.

An emission estimate was generated for each chemical surrogate category for each management process or process type. Process parameters and surrogate properties used to estimate emission factors are presented in Table D-16. Emission estimates generally were calculated on a mass-per-unit-time basis (i.e., grams per second) and scaled by the appropriate operating times to get emissions in megagrams per year. The emission values then were divided by the annual organic input quantity for the respective model unit in megagrams per year. The emission factors for each model unit, emissions per megagram of throughput, were then multiplied by the appropriate weighting factor, and those products were summed to get the weighted emission factor for each waste management process.

A set of weighted emission factors was generated for all surrogate classes and all the SAM management processes. In addition to emission factors for process-related emissions, emission factors were developed for transfer and handling related emissions. Also calculated were factors used to predict biodegradation quantities; equations for biodegradation rate are presented in Appendix C. These TSDF emission factors were developed to be general representations of emissions and biodegradation fractions for all waste types, waste concentrations, and waste forms as well as management process combinations and process unit sizes on a nationwide basis. As such, these emission factors were incorporated into the SAM program file that is used to generate the SAM nationwide emission estimates. A listing of the TSDF emission factor files is included in Table D-17. A separate block of numbers is presented for each management process with rows denoting surrogate category and columns denoting: (1) surrogates, (2) annual fraction of surrogate emitted to air as a process emission, (3) annual fraction biodegraded, (4) annual fraction emitted from handling and loading, (5) annual fraction emitted from spills, and (6) annual fraction emitted from equipment leaks.

TABLE D-16. HAZARDOUS WASTE MANAGEMENT PROCESS PARAMETERS AND WASTE CONSTITUENT PROPERTIES USED TO ESTIMATE EMISSION FACTORS FOR SOURCE ASSESSMENT MODEL[a]

Waste management process	Physical/chemical waste form	Surrogate group	Waste organic concentration
Covered tank storage (S02)	Organic liquid	Vapor pressure	Pure component
Uncovered tank storage (S02)	Aqueous liquid	Henry's law	1,000 ppm
Storage impoundments (S04)	Aqueous liquid	Henry's law	1,000 ppm
Covered quiescent treatment tanks (T01)	Aqueous liquid	Henry's law	1,000 ppm
Uncovered quiescent treatment tanks (T01)	Aqueous liquid	Henry's law	1,000 ppm
Uncovered aerated treatment tanks (T01)	Aqueous liquid	Henry's law	1,000 ppm
Quiescent treatment impoundments (T02)	Aqueous liquid	Henry's law	1,000 ppm
Aerated treatment impoundments (T02)	Aqueous liquid	Henry's law	1,000 ppm
Disposal impoundments (D83)	Aqueous liquid	Henry's law	1,000 ppm
Terminal loading impoundments and tanks (L01)	Aqueous liquid	Henry's law	1,000 ppm
Terminal loading storage tanks (L03)	Organic liquid	Vapor pressure	Pure component
Wastepiles (S03)	Organic/aqueous liquid (2 phase)	Vapor pressure	5%
Landfills (D80)	Organic/aqueous liquid (2 phase)	Vapor pressure	5%
Land treatment (D81)	Organic liquid	Vapor pressure	--

[a]This table presents, for those air emission models that require a waste concentration as input, necessary information to estimate organic emission factors from hazardous waste management facilities used in the Source Assessment Model. Additional information and data are presented in Appendix C, Section C.2, which discusses model treatment, storage, and disposal facility (TSDF) waste management units.

TABLE D-17. EMISSION FACTOR FILES[a,b]

	Weighted emission factors for container and drum storage (S01) using vapor pressure surrogates				Weighted emission factors for dumpster storage (S01) using vapor pressure surrogates				Weighted emission factors for covered tank storage (S02) using vapor pressure surrogates			
Surrogate	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)[c]	k(fug)
1	--	0.0001	0.0013	0.0154	1.0000	0.0001	--	--	0.0012	0.0000	0.0000	0.003034
2	--	0.0001	0.0011	0.0154	1.0000	0.0001	--	--	0.0011	0.0000	0.0000	0.003034
3	--	0.0001	0.0018	0.0154	1.0000	0.0001	--	--	0.0017	0.0000	0.0000	0.003034
4	--	0.0001	0.0000	0.0154	0.4786	0.0001	--	--	0.0000	0.0000	0.0000	0.003034
5	--	0.0001	0.0000	0.0154	0.4014	0.0001	--	--	0.0000	0.0000	0.0000	0.003034
6	--	0.0001	0.0000	0.0154	0.8269	0.0001	--	--	0.0000	0.0000	0.0000	0.003034
7	--	0.0001	0.0000	0.0154	0.0000	0.0001	--	--	0.0000	0.0000	0.0000	0.003034
8	--	0.0001	0.0000	0.0154	0.0000	0.0001	--	--	0.0000	0.0000	0.0000	0.003034
9	--	0.0001	0.0000	0.0154	0.0000	0.0001	--	--	0.0000	0.0000	0.0000	0.003034
10	--	0.0001	0.0069	0.0154	1.0000	0.0001	--	--	0.0000	0.0000	0.0000	0.003034
11	--	0.0001	0.0140	0.0154	1.0000	0.0001	--	--	0.0000	0.0000	0.0000	0.003034
12	--	0.0001	0.0140	0.0154	1.0000	0.0001	--	--	0.0000	0.0000	0.0000	0.003034

See notes at end of table.

(continued)

TABLE D-17 (continued)

Surrogate	Weighted emission factors for uncovered tank storage (S02) using Henry's law constant surrogates				Weighted emission factors for wastepiles (S03) using vapor pressure surrogates				Weighted emission factors for storage impoundments (S04) using Henry's law surrogates			
	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)	k(fug)
1	0.5510	0.0000	--	0.00304	0.0125	0.0000	--	--	0.7460	0.0000	--	0.00058
2	0.5480	0.0000	--	0.00304	0.0115	0.0000	--	--	0.7330	0.0000	--	0.00058
3	0.5510	0.0000	--	0.00304	0.0175	0.0000	--	--	0.7470	0.0000	--	0.00058
4	0.5450	0.0000	--	0.00304	0.0020	0.0000	--	--	0.7390	0.0000	--	0.00058
5	0.5410	0.0000	--	0.00304	0.0020	0.0000	--	--	0.7280	0.0000	--	0.00058
6	0.6460	0.0000	--	0.00304	0.0020	0.0000	--	--	0.6630	0.0000	--	0.00058
7	0.1180	0.0000	--	0.00304	0.0000	0.0000	--	--	0.0590	0.0000	--	0.00058
8	0.1680	0.0000	--	0.00304	0.0000	0.0000	--	--	0.0930	0.0000	--	0.00058
9	0.1680	0.0000	--	0.00304	0.0000	0.0000	--	--	0.0930	0.0000	--	0.00058
10					0.0275	0.0000	--	--				
11					0.0275	0.0000	--	--				
12					0.0275	0.0000	--	--				

See notes at end of table.

(continued)

TABLE D-17 (continued)

Surrogate	Weighted emission factors for covered quiescent treatment tanks (TØ1) using Henry's law constant surrogates				Weighted emission factors for uncovered quiescent treatment tanks (TØ1) using Henry's law constant surrogates				Weighted emission factors for uncovered aerated treatment tanks (TØ1) using Henry's law constant surrogates				
	f(air)	f(sp)	f(load)[c]	k(fug)	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(bio)	f(sp)	f(load)	k(fug)
1	0.0113	0.0000	0.0000	0.000066	0.1120	0.0000	--	0.000066	0.8780	0.0510	0.0000	--	0.000013
2	0.0022	0.0000	0.0000	0.000066	0.1060	0.0000	--	0.000066	0.7790	0.0110	0.0000	--	0.000013
3	0.0422	0.0000	0.0000	0.000066	0.1120	0.0000	--	0.000066	0.9550	0.0000	0.0000	--	0.000013
4	0.0002	0.0000	0.0000	0.000066	0.0990	0.0000	--	0.000066	0.1450	0.4200	0.0000	--	0.000013
5	0.0002	0.0000	0.0000	0.000066	0.0910	0.0000	--	0.000066	0.1810	0.0020	0.0000	--	0.000013
6	0.0001	0.0000	0.0000	0.000066	0.0640	0.0000	--	0.000066	0.0940	0.0060	0.0000	--	0.000013
7	0.0000	0.0000	0.0000	0.000066	0.0010	0.0000	--	0.000066	0.0005	0.3100	0.0000	--	0.000013
8	0.0000	0.0000	0.0000	0.000066	0.0030	0.0000	--	0.000066	0.0020	0.0550	0.0000	--	0.000013
9	0.0000	0.0000	0.0000	0.000066	0.0030	0.0000	--	0.000066	0.0020	0.0550	0.0000	--	0.000013

See notes at end of table.

(continued)

TABLE D-17 (continued)

	Weighted emission factors for quiescent treatment impoundments (T02) using Henry's law constant surrogates				Weighted emission factors for aerated impoundments (T02) using Henry's law constant surrogates					Weighted emission factors for incineration (T03) using vapor pressure surrogates			
Surrogate	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(bio)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)	k(fug)
1	0.5180	0.0000	--	0.000009	0.7120	0.0830	0.0000	--	0.000009	0.0001	0.0000	--	0.00045
2	0.5000	0.0000	--	0.000009	0.9780	0.0010	0.0000	--	0.000009	0.0001	0.0000	--	0.00045
3	0.5190	0.0000	--	0.000009	0.9900	0.0000	0.0000	--	0.000009	0.0001	0.0000	--	0.00045
4	0.5060	0.0000	--	0.000009	0.3290	0.7700	0.0000	--	0.000009	0.0001	0.0000	--	0.00045
5	0.4910	0.0000	--	0.000009	0.8330	0.0060	0.0000	--	0.000009	0.0001	0.0000	--	0.00045
6	0.4090	0.0000	--	0.000009	0.7470	0.0040	0.0000	--	0.000009	0.0001	0.0000	--	0.00045
7	0.0170	0.0000	--	0.000009	0.0040	0.9150	0.0000	--	0.000009	0.0001	0.0000	--	0.00045
8	0.0260	0.0000	--	0.000009	0.0480	0.3180	0.0000	--	0.000009	0.0001	0.0000	--	0.00045
9	0.0260	0.0000	--	0.000009	0.0480	0.3180	0.0000	--	0.000009		0.0000	--	0.00045
10											0.0000	--	0.00045
11											0.0000	--	0.00045
12											0.0000	--	0.00045

(continued)

See notes at end of table.

TABLE D-17 (continued)

Surrogate	Weighted emissions factors for injection wells (D79) using vapor pressure surrogates				Weighted emission factors for onsite active landfills (D80) using vapor pressure surrogates				Emission factors for onsite closed landfills (D80) using vapor pressure surrogates			
	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)	k(fug)
1	--	0.0000	--	0.00009	0.2230	0.0000	--	--	0.0091	0.0000	--	--
2	--	0.0000	--	0.00009	0.2070	0.0000	--	--	0.0087	0.0000	--	--
3	--	0.0000	--	0.00009	0.3110	0.0000	--	--	0.0171	0.0000	--	--
4	--	0.0000	--	0.00009	0.0300	0.0000	--	--	0.0002	0.0000	--	--
5	--	0.0000	--	0.00009	0.0300	0.0000	--	--	0.0001	0.0000	--	--
6	--	0.0000	--	0.00009	0.0410	0.0000	--	--	0.0003	0.0000	--	--
7	--	0.0000	--	0.00009	0.0002	0.0000	--	--	0.0000	0.0000	--	--
8	--	0.0000	--	0.00009	0.0002	0.0000	--	--	0.0000	0.0000	--	--
9	--	0.0000	--	0.00009	0.0002	0.0000	--	--	0.0000	0.0000	--	--
10	--	0.0000	--	0.00009	0.4870	0.0000	--	--	0.0435	0.0000	--	--
11	--	0.0000	--	0.00009	0.7000	0.0000	--	--	0.0951	0.0000	--	--
12	--	0.0000	--	0.00009	0.7000	0.0000	--	--	0.0951	0.0000	--	--

See notes at end of table.

(continued)

TABLE D-17 (continued)

	Weighted emission factors for commercial active landfills (D80) using vapor pressure surrogates				Weighted emission factors for closed commercial landfills (D80) using vapor pressure surrogates				Weighted emission factors for land treatment surface application (D81) using vapor pressure surrogates			
Surrogate	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)	k(fug)
1	0.1110	0.0000	--	--	0.0076	0.0000	--	--	1.0000	0.0000	--	--
2	0.1030	0.0000	--	--	0.0070	0.0000	--	--	1.0000	0.0000	--	--
3	0.1550	0.0000	--	--	0.0146	0.0000	--	--	1.0000	0.0000	--	--
4	0.0160	0.0000	--	--	0.0001	0.0000	--	--	0.2663	0.0000	--	--
5	0.0150	0.0000	--	--	0.0001	0.0000	--	--	0.3943	0.0000	--	--
6	0.0210	0.0000	--	--	0.0002	0.0000	--	--	0.8551	0.0000	--	--
7	0.0001	0.0000	--	--	0.0000	0.0000	--	--	0.0020	0.0000	--	--
8	0.0001	0.0000	--	--	0.0000	0.0000	--	--	0.0020	0.0000	--	--
9	0.0001	0.0000	--	--	0.0000	0.0000	--	--	0.0020	0.0000	--	--
10	0.2420	0.0000	--	--	0.0367	0.0000	--	--	1.0000	0.0000	--	--
11	0.3560	0.0000	--	--	0.0798	0.0000	--	--	1.0000	0.0000	--	--
12	0.3560	0.0000	--	--	0.0798	0.0000	--	--	1.0000	0.0000	--	--

See notes at end of table.

(continued)

TABLE D-17 (continued)

	Weighted emission factors for land treatment subsurface injection (D81) using vapor pressure surrogates				Weighted emission factors for disposal impoundments (D83) using Henry's law surrogates				Weighted emission factors for terminal loading of containers (L01)		
Surrogate	f(air)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)	k(fug)	f(sp)	f(load)	k(fug)
1	0.8480	0.0000	--	--	1.0000	0.0000	--	0.00011	0.0001	--	0.0000
2	0.9640	0.0000	--	--	1.0000	0.0000	--	0.00011	0.0001	--	0.0000
3	0.9960	0.0000	--	--	1.0000	0.0000	--	0.00011	0.0001	--	0.0000
4	0.1510	0.0000	--	--	1.0000	0.0000	--	0.00011	0.0001	--	0.0000
5	0.3310	0.0000	--	--	1.0000	0.0000	--	0.00011	0.0001	--	0.0000
6	0.8320	0.0000	--	--	1.0000	0.0000	--	0.00011	0.0001	--	0.0000
7	0.0020	0.0000	--	--	0.4700	0.0000	--	0.00011	0.0001	--	0.0000
8	0.0020	0.0000	--	--	0.6300	0.0000	--	0.00011	0.0001	--	0.0000
9	0.0020	0.0000	--	--	0.6300	0.0000	--	0.00011	0.0001	--	0.0000
10	0.9550	0.0000	--	--					0.0001	--	0.0000
11	0.9990	0.0000	--	--					0.0001	--	0.0000
12	0.9990	0.0000	--	--					0.0001	--	0.0000

See notes at end of table.

(continued)

TABLE D-17 (continued)

Surrogate	Weighted emission factors for terminal loading from impoundments and tanks (L02) using Henry's law surrogates			Weighted emission factors for terminal loading from storage tanks (L03) using vapor pressure surrogates			Weighted emission factors for waste fixation using vapor pressure surrogates[d]			
	f(sp)	f(load)	k(fug)	f(sp)	f(load)	k(fug)	f(air)	f(sp)	f(load)	k(fug)
1	0.00001	0.0013	0.00799	0.00001	0.0013	0.00799	0.6800	0.0000	--	--
2	0.00001	0.0011	0.00799	0.00001	0.0013	0.00799	0.6800	0.0000	--	--
3	0.00001	0.0018	0.00799	0.00001	0.0018	0.00799	0.6800	0.0000	--	--
4	0.00001	0.0000	0.00799	0.00001	0.0000	0.00799	0.5300	0.0000	--	--
5	0.00001	0.0000	0.00799	0.00001	0.0000	0.00799	0.5300	0.0000	--	--
6	0.00001	0.0000	0.00799	0.00001	0.0000	0.00799	0.5300	0.0000	--	--
7	0.00001	0.0000	0.00799	0.00001	0.0000	0.00799	0.0500	0.0000	--	--
8	0.00001	0.0000	0.00799	0.00001	0.0000	0.00799	0.0500	0.0000	--	--
9	0.00001	0.0000	0.00799	0.00001	0.0000	0.00799	0.0500	0.0000	--	--
10				0.00001	0.0069	0.00799	0.6800	0.0000	--	--
11				0.00001	0.0140	0.00799	0.6800	0.0000	--	--
12				0.00001	0.0140	0.00799	0.6800	0.0000	--	--

Note: Dash indicates emission factors not applicable.

[a]Some waste management processes, such as S01, S02, and S03, lack a column for biodegradation fraction. They have no biodegradation component, or biodegradation has been considered in the air emission factor determination, and they are read in SAM as zeros.

Values of 0.0000 do not imply that the emission factors equal zero. Rather, 0.000 reflects values less than 0.001 percent.

[b]The f(___) in the column headings represent fractions emitted or degraded. The k(f) in the last column represents fractions emitted from equipment (e.g., pumps, valves, open-end line, etc.).

f(air) = process emissions fraction leaks associated with the waste management process.
f(bio) = biodegradation fraction
f(sp) = spills fraction
k(f) = equipment leak fraction.

[c]Loading emissions included in f(air).

[d]Emission factors for waste fixation are based on the information and data contained in a report prepared by Acurex Corp. for the U.S. EPA titled "Volatile Emissions from Stabilized Waste in Hazardous Waste Landfills," Project 8186, Contract 68-02-3993, January 23, 1987.

D.2.5 Control Technology and Cost File

A file was developed for the SAM that provides control device efficiencies for each emission control alternative (see Chapter 4.0) that is applicable to each waste management process. Certain control options are specific to waste form. The control technology file provides control efficiencies for land treatment alternatives and add-on control alternatives among others. The control file is a combined file that includes control costs (see Appendix H) as well as control efficiencies. Model waste compositions defined in Appendix C, Section C.2.2, provided the bases for estimating control costs and control efficiencies by waste form. Appendix H discusses the derivation of the estimates in detail.

Tables D-18 and D-19 present the control cost file broken down by emission source and control option. A key is provided at the bottom of the table that explains the columns and how they are used in the SAM.

One important note is that the control cost profile requires that controls and costs be developed for all physical/chemical waste forms even though certain forms and management processes are incompatible or improbable (e.g., storage of a solid hazardous waste in a closed storage tank or storage of an organic liquid waste in an open impoundment). The SAM dilutes incompatible waste forms, when necessary, but cannot redefine the waste form. Therefore, the cost/control file was modified to estimate emission reductions and costs for all waste forms. The SAM will substitute the control costs for a similar waste form if there are no cost factors for a particular (incompatible) form. For example, cost factors for control of dilute aqueous wastes will be used for estimating control costs of a (diluted) aqueous sludge slurry because this waste form did not have control costs developed specifically.

Costs were developed in a way that allows one to estimate capital and annual costs based on total volume waste throughput. Within each management process, total capital investment and annual operating costs were determined for a range of model units and the appropriate add-on control technologies applicable to these processes. The same waste management process weighting factors used to develop emission factors were used to develop weighted cost factors. Estimation of the costs for applying emission controls to TSDF waste management units would ideally be done using specific information about the characteristics of the waste

TABLE D-18. SUPPRESSION AND ADD-ON CONTROL COST FILE USED BY THE SOURCE ASSESSMENT MODEL[a,b]

TSDF process code (1)	TSDF emission source (2)	Waste form (3)	Volatility class (4)	Control index (5)	Emission control option (6)	Control efficiency: Suppression (7)	Control efficiency: Emission control (8)	Transfer code (9)	Loading (10)	Service life (11)	Cost function (12)	Total capital investment, $: a (13)	Total capital investment, $: b x Q (14)	Cost function (15)	Annual operating cost, $: a (16)	Annual operating cost, $: b x Q (17)
S01	Drum Storage	VOC-cont Solid	All	1	Vent to Car Ads		95.00	C	A	20	Linear	0.00	49.000	Linear	0.00	15.000
S01	Drum Storage	Aq Sldg/Slurry	All	1	Vent to Car Ads		95.00	C	A	20	Linear	0.00	72.000	Linear	0.00	21.000
S01	Drum Storage	Dilute Aq	All	1	Vent to Car Ads		95.00	C	A	20	Linear	0.00	89.000	Linear	0.00	27.000
S01	Drum Storage	Org Liquid	All	1	Vent to Car Ads		95.00	C	A	20	Linear	0.00	91.000	Linear	0.00	27.000
S01	Drum Storage	Org Sldg/Slurry	All	1	Vent to Car Ads		95.00	C	A	20	Linear	0.00	64.000	Linear	0.00	20.000
S01	Drum Storage	2-Phase Aq/Org	All	1	Vent to Car Ads		95.00	C	A	20	Linear	0.00	91.000	Linear	0.00	27.000
S01	Dumpster	VOC-cont Solid	All	2	Dumpster Cover	99.00				20	Linear	0.00	6.250	Linear	0.00	1.670
S01	Dumpster	Aq Sldg/Slurry	All	2	Dumpster Cover	99.00				20	Linear	0.00	9.375	Linear	0.00	2.500
S01	Dumpster	Dilute Aq	All	2	Dumpster Cover	99.00				20	Linear	0.00	25.030	Linear	0.00	6.670
S01	Dumpster	Org Liquid	All	2	Dumpster Cover	99.00				20	Linear	0.00	25.640	Linear	0.00	6.840
S01	Dumpster	Org Sldg/Slurry	All	2	Dumpster Cover	99.00				20	Linear	0.00	17.860	Linear	0.00	4.980
S01	Dumpster	2-Phase Aq/Org	All	2	Dumpster Cover	99.00				20	Linear	0.00	25.610	Linear	0.00	6.830
S01	Fugitives- Drum Load	Aq Sldg/Slurry	All	3				C								
S01	Fugitives- Drum Load	Dilute Aq	All	3				C								
S01	Fugitives- Drum Load	2-Phase Aq/Dry	All	3				C								
S01	Fugitives- Drum Load	Org Liquid	All	3				C								
S01	Fugitives- Drum Load	Org Sldg/Slurry	All	3				C								
S01	Drum Loading	VOC-Cont Solid	All	4				C	A							
S01	Drum Loading	Aq Sldg/Slur	All	4				C	A							
S01	Drum Loading	Dil Aqueous	All	4				C	A							
S01	Drum Loading	Org Liquid	All	4				C	A							
S01	Drum Loading	Org Sldg/Slurry	All	4				C	A							
S01	Drum Loading	2-Phase Aq/Org	All	4				C	A							
S02	Tank Storage	Sub 2xx for 1xx	All	1	IFR, CAds, Vent to CD	84.5		D		10	Linear	0.00	9.740	Linear	0.00	3.290
S02	Tank Storage	Aq Sldg/Slurry	All	1	IFR, CAds, Vent to CD	88.5		D		10	Linear	0.00	9.740	Linear	0.00	3.290
S02	Tank Storage	Dilute Aq	All	1	IFR, CAds, Vent to CD	84.5		D		10	Linear	0.00	13.210	Linear	0.00	9.450
S02	Tank Storage	Org Liquid	All	1	IFR, CAds, Vent to CD	91.75		D		10	Linear	0.00	12.360	Linear	0.00	4.720
S02	Tank Storage	Org Sldg/Slurry	All	1	IFR, CAds, Vent to CD	91.5		D		10	Linear	0.00	11.080	Linear	0.00	5.710
S02	Tank Storage	2-Phase Aq/Org	All	1	IFR, CAds, Vent to CD	86.5		D		10	Linear	0.00	10.740	Linear	0.00	4.870
S02	Tank Storage	Sub 2xx for 1xx	All	2	Fixed Roof	86.4		D		20	Linear	0.00	14.660	Linear	0.00	1.070
S02	Tank Storage	Aq Sldg/Slurry	All	2	Fixed Roof	98.70		D		20	Linear	0.00	14.660	Linear	0.00	1.070
S02	Tank Storage	Dilute Aq	All	2	Fixed Roof	86.40		D		20	Linear	0.00	18.470	Linear	0.00	1.360
S02	Tank Storage	Org Liquid	All	2	Fixed Roof	99.90		D		20	Linear	0.00	18.590	Linear	0.00	1.370
S02	Tank Storage	Org Sldg/Slurry	All	2	Fixed Roof	99.85		D		20	Linear	0.00	15.310	Linear	0.00	1.120

(continued)

See notes at end of table.

TABLE D-18 (continued)

TSDF process code (1)	TSDF emission source (2)	Waste form (3)	Volatility class (4)	Control index (5)	Emission control option (6)	Control efficiency: Suppression (7)	Control efficiency: Emission control (8)	Transfer code (9)	Loading (10)	Service life (11)	Cost function (12)	Total capital investment, $: a (13)	Total capital investment, $: b x Q (14)	Cost function (15)	Annual operating cost, $: a (16)	Annual operating cost, $: b x Q (17)
S02	Tank Storage	2-Phase Aq/Org	All	2	Fixed Roof	90.00		D		20	Linear	0.00	15.720	Linear	0.00	1.160
S02	Tank Storage	Sub 2xx for 1xx	All	3	Roof, IFR, CAds, Vent	97.9		D		10	Linear	0.00	20.980	Linear	0.00	3.980
S02	Tank Storage	Aq Sldg/Slurry	All	3	Roof, IFR, CAds, Vent	99.85		D		10	Linear	0.00	20.980	Linear	0.00	3.980
S02	Tank Storage	Dilute Aq	All	3	Roof, IFR, CAds, Vent	97.90		D		10	Linear	0.00	27.660	Linear	0.00	10.500
S02	Tank Storage	Org Liquid	All	3	Roof, IFR, CAds, Vent	99.99		D		10	Linear	0.00	26.840	Linear	0.00	6.150
S02	Tank Storage	Org Sldg/Slurry	All	3	Roof, IFR, CAds, Vent	99.99		D		10	Linear	0.00	22.780	Linear	0.00	6.390
S02	Tank Storage	2-Phase Aq/Org	All	3	Roof, IFR, Cads, Vent	98.70		D		10	Linear	0.00	22.550	Linear	0.00	6.690
S02	Fugitives- Tank Load	Aq Sldg/Slurry	All	4				D								
S02	Fugitives- Tank Load	Dilut Aq	All	4				D								
S02	Fugitives- Tank Load	2-Phase Aq/Org	All	4				D								
S02	Fugitives- Tank Load	Org Liquid	All	4				D								
S02	Fugitives- Tank Load	Org Sldg/Slurry	All	4				D								
S03	Waste Pile	Aq Sldg/Slurry	All	1	HD Cover 30 mil	99.70				5	Linear	0.00	0.310	Linear	0.00	0.080
S03	Waste Pile	Sub 2xx for 3xx	All	1	HD Cover 30 mil	99.70				5	Linear	0.00	0.310	Linear	0.00	0.080
S03	Waste Pile	Sub 7xx for 4xx	All	1	HD Cover 30 mil	49.30				5	Linear	0.00	0.310	Linear	0.00	0.080
S03	Waste Pile	Sub 7xx for 5xx	All	1	HD Cover 30 mil	49.30				5	Linear	0.00	0.310	Linear	0.00	0.080
S03	Waste Pile	2-Phase Aq/Org	All	1	HD Cover 30 mil	49.30				5	Linear	0.00	0.310	Linear	0.00	0.080
S03	Waste Pile	VOC-cont Solid	All	1	HD Cover 30 mil	0.00				5	Linear	0.00	0.310	Linear	0.00	0.080
S04	Stor Impd Surface	Sub 2xx for 1xx	All	1	Syn Membrane	85.00		I		10	Linear	0.00	1.850	Linear	0.00	0.240
S04	Stor Impd Surface	Aq Sldg/Slurry	All	1	Syn Membrane	85.00		I		10	Linear	0.00	1.850	Linear	0.00	0.240
S04	Stor Impd Surface	Dilute Aq	All	1	Syn Membrane	85.00		I		10	Linear	0.00	1.850	Linear	0.00	0.240
S04	Stor Impd Surface	Sub 2xx for 4xx	All	1	Syn Membrane	85.00		I		10	Linear	0.00	1.850	Linear	0.00	0.240
S04	Stor Impd Surface	Sub 2xx for 5xx	All	1	Syn Membrane	85.00		I		10	Linear	0.00	1.850	Linear	0.00	0.240
S04	Stor Impd Surface	2-Phase Aq/Org	All	1	Syn Membrane	85.00		I		10	Linear	0.00	1.850	Linear	0.00	0.240
S04	Stor Impd Surface	Sub 2xx for 1xx	All	2	Struct w Car Adsorp	95.00		I		10	Linear	0.00	10.760	Linear	0.00	3.030
S04	Stor Impd Surface	Aq Sldg/Slurry	All	2	Struct w Car Adsorp	95.00		I		10	Linear	0.00	10.760	Linear	0.00	3.030
S04	Stor Impd Surface	Dilute Aq	All	2	Struct w Car Adsorp	95.00		I		10	Linear	0.00	9.430	Linear	0.00	2.270
S04	Stor Impd Surface	Sub 2xx for 4xx	All	2	Struct w Car Adsorp	95.00		I		10	Linear	0.00	10.760	Linear	0.00	3.030
S04	Stor Impd Surface	Sub 2xx for 5xx	All	2	Struct w Car Adsorp	95.00		I		10	Linear	0.00	10.760	Linear	0.00	3.030
S04	Stor Impd Surface	2-Phase Aq/Org	All	2	Struct w Car Adsorp	95.00		I		10	Linear	0.00	9.430	Linear	0.00	2.270
S04	Fugitives- Imp Load	Aq Sldg/Slurry	All	3				I								
S04	Fugitives- Imp Load	Dilut Aq	All	3				I								
S04	Fugitives- Imp Load	2-Phase Aq/Org	All	3				I								

See notes at end of table.

(continued)

TABLE D-18 (continued)

TSDF process code (1)	TSDF emission source (2)	Waste form (3)	Volatility class (4)	Control index (5)	Emission control option (6)	Control efficiency: Suppression (7)	Control efficiency: Emission control (8)	Transfer code (9)	Loading (10)	Service life (11)	Cost function (12)	Total capital investment, $: a (13)	Total capital investment, $: b x Q (14)	Cost function (15)	Annual operating cost, $: a (16)	Annual operating cost, $: b x Q (17)
S04	Fugitives- Imp Load	Org Liquid	All	3				I								
S04	Fugitives- Imp Load	Org Sldg/Slurry	All	3				I								
T01	Tank Surface	Sub 2xx for 1xx	All	1	Fixed Roof	87.50		H		20	Linear	0.00	0.380	Linear	0.00	0.030
T01	Tank Surface	Aq Sldg/Slurry	All	1	Fixed Roof	98.20		H		20	Linear	0.00	0.380	Linear	0.00	0.030
T01	Tank Surface	Dilute Aq	All	1	Fixed Roof	87.50		H		20	Linear	0.00	0.380	Linear	0.00	0.030
T01	Tank Surface	Org Liquid	All	1	Fixed Roof	99.22		H		20	Linear	0.00	0.380	Linear	0.00	0.030
T01	Tank Surface	Org Sldg/Slurry	All	1	Fixed Roof	98.99		H		20	Linear	0.00	0.380	Linear	0.00	0.030
T01	Tank Surface	2-Phase Aq/Org	All	1	Fixed Roof	93.50		H		20	Linear	0.00	0.380	Linear	0.00	0.030
T01	Tank Surface	Sub 2xx for 1xx	All	2	Roof, IFR, CAds, Vent	95.40		H		10	Linear	0.00	0.570	Linear	0.00	0.130
T01	Tank Surface	Aq Sldg/Slurry	All	2	Roof, IFR, CAds, Vent	99.70		H		10	Linear	0.00	0.570	Linear	0.00	0.130
T01	Tank Surface	Dilute Aq	All	2	Roof, IFR, CAds, Vent	95.40		H		10	Linear	0.00	1.160	Linear	0.00	0.390
T01	Tank Surface	Org Liquid	All	2	Roof, IFR, CAds, Vent	99.96		H		10	Linear	0.00	0.710	Linear	0.00	0.280
T01	Tank Surface	Org Sldg/Slurry	All	2	Roof, IFR, CAds, Vent	99.95		H		10	Linear	0.00	0.800	Linear	0.00	0.300
T01	Tank Surface	2-Phase Aq/Org	All	2	Roof, IFR, Cads, Vent	97.10		H		10	Linear	0.00	0.800	Linear	0.00	0.360
T01	Tank Surface	Sub 2xx for 1xx	All	3	IFR, CAds, Vent to CD	84.50		H		10	Linear	0.00	0.220	Linear	0.00	0.10
T01	Tank Surface	Aq Sldg/Slurry	All	3	IFR, CAds, Vent to CD	88.50		H		10	Linear	0.00	0.220	Linear	0.00	0.10
T01	Tank Surface	Dilute Aq	All	3	IFR, CAds, Vent to CD	84.50		H		10	Linear	0.00	0.820	Linear	0.00	0.37
T01	Tank Surface	Org Liquid	All	3	IFR, CAds, Vent to CD	91.75		H		10	Linear	0.00	0.360	Linear	0.00	0.25
T01	Tank Surface	Org Sldg/Slurry	All	3	IFR, Cads, Vent to CD	91.50		H		10	Linear	0.00	0.360	Linear	0.00	0.27
T01	Tank Surface	2-Phase Aq/Org	All	3	IFR, Cads, Vent to CD	86.50		H		10	Linear	0.00	0.800	Linear	0.00	0.36
T01	Tank Surface	Sub 2xx for 1xx	All	4	Roof, Vent to CAds	95.00		G		10	Linear	0.00	0.410	Linear	0.00	0.19
T01	Tank Surface	Aq Sldg/Slurry	All	4	Roof, Vent to CAds	95.00		G		10	Linear	0.00	0.410	Linear	0.00	0.19
T01	Tank Surface	Dilute Aq	All	4	Roof, Vent to CAds	95.00		G		10	Linear	0.00	0.420	Linear	0.00	0.30
T01	Tank Surface	Sub 2xx for 4xx	All	4	Roof, Vent to CAds	95.00		G		10	Linear	0.00	0.410	Linear	0.00	0.19
T01	Tank Surface	Sub 2xx for 5xx	All	4	Roof, Vent to CADs	95.00		G		10	Linear	0.00	0.410	Linear	0.00	0.19
T01	Tank Surface	Sub 2xx for 7xx	All	4	Roof, Vent to CAds	95.00		G		10	Linear	0.00	0.410	Linear	0.00	0.19
T01	Fugitives- Q Tank Ld	Aq Sldg/Slurry	All	5				H								
T01	Fugitives- Q Tank Ld	Dilut Aq	All	5				H								
T01	Fugitives- Q Tank Ld	Org Sldg/Slurry	All	5				H								
T01	Fugitives- Q Tank Ld	Org Liquid	All	5				H								
T01	Fugitives- Q Tank Ld	Org Sldg/Slurry	All	5				H								
T01	Fugitives- A Tank Ld	Aq Sldg/Slurry	All	6				G								
T01	Fugitives- A Tank Ld	Dilut Aq	All	6				G								
T01	Fugitives- A Tank Ld	2-Phase Aq/Org	All	6				G								

See notes at end of table.

(continued)

TABLE D-18 (continued)

TSDF process code (1)	TSDF emission source (2)	Waste form (3)	Volatility class (4)	Control index (5)	Emission control option (6)	Control efficiency: Suppression (7)	Control efficiency: Emission control (8)	Transfer code (9)	Loading (10)	Service life (11)	Cost function (12)	Total capital investment, $: a (13)	Total capital investment, $: b x Q (14)	Cost function (15)	Annual operating cost, $: a (16)	Annual operating cost, $: b x Q (17)
T01	Fugitives- A Tank Ld	Org Liquid	All	6				G								
T01	Fugitives- A Tank Ld	Org Sldg/Slurry	All	6				G								
T02	Treat Impd Surface	Sub 2xx for 1xx	All	1	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.600	Linear	0.00	0.800
T02	Treat Impd Surface	Aq Sldg/Slurry	All	1	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.600	Linear	0.00	0.800
T02	Treat Impd Surface	Dilute Aq	All	1	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.300	Linear	0.00	0.500
T02	Treat Impd Surface	Sub 2xx for 4xx	All	1	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.600	Linear	0.00	0.800
T02	Treat Impd Surface	Sub 2xx for 5xx	All	1	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.600	Linear	0.00	0.800
T02	Treat Impd Surface	2-Phase Aq/Org	All	1	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.300	Linear	0.00	0.500
T02	Treat Impd Surface	Sub 2xx for 1xx	All	2	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.900	Linear	0.00	1.200
T02	Treat Impd Surface	Aq Sldg/Slurry	All	2	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.900	Linear	0.00	1.200
T02	Treat Impd Surface	Dilute Aq	All	2	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.500	Linear	0.00	0.700
T02	Treat Impd Surface	Sub 2xx for 4xx	All	2	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.900	Linear	0.00	1.200
T02	Treat Impd Surface	Sub 2xx for 5xx	All	2	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.900	Linear	0.00	1.200
T02	Treat Impd Surface	2-Phase Aq/Org	All	2	Stuct & Car Adsorp	95.00		J		10	Linear	0.00	2.500	Linear	0.00	0.700
T02	Fugitives- Imp Load	Aq Sldg/Slurry	All	3				J								
T02	Fugitives- Imp Load	Dilut Aq	All	3				J								
T02	Fugitives- Imp Load	2-Phase Aq/Org	All	3				J								
T02	Fugitives- Imp Load	Org Liquid	All	3				J								
T02	Fugitives- Imp Load	Org Sldg/Slurry	All	3				J								
T02	Trt Impd Surface	Sub 2xx for 1xx	All	5	Syn Membrane	85.00		J		10	Linear	0.00	0.460	Linear	0.00	0.060
T02	Trt Impd Surface	Aq Sldg/Slurry	All	5	Syn Membrane	85.00		J		10	Linear	0.00	0.460	Linear	0.00	0.060
T02	Trt Impd Surface	Dilute Aq	All	5	Syn Membrane	85.00		J		10	Linear	0.00	0.460	Linear	0.00	0.060
T02	Trt Impd Surface	Sub 2xx for 4xx	All	5	Syn Membrane	85.00		J		10	Linear	0.00	0.460	Linear	0.00	0.060
T02	Trt Impd Surface	Sub 2xx for 5xx	All	5	Syn Membrane	85.00		J		10	Linear	0.00	0.460	Linear	0.00	0.060
T02	Trt Impd Surface	2-Phase Aq/Org	All	5	Syn Membrane	85.00		J		10	Linear	0.00	0.460	Linear	0.00	0.060
T03		VOC-cont Solid		1				E								
T03		Aq Sldg/Slurry		1				E								
T03		Dilute Aq		1				E								
T03		Org Liquid		1				E								
T03		Org Sldg/Slurry		1				E								
T03				1				E								
T03		2-Phase Aq/Org		1				E								
T04	Tank Surface	Sub 2xx for 1xx	All	3	IFR,CAds,Vent to CD	84.50		H		10	Linear	0.00	0.220	Linear	0.00	0.10
T04	Tank Surface	Aq Sldg/Slurry	All	3	IFR,CAds,Vent to CD	88.50		H		10	Linear	0.00	0.220	Linear	0.00	0.10

See notes at end of table.

(continued)

TABLE D-18 (continued)

TSDF process code (1)	TSDF emission source (2)	Waste form (3)	Volatility class (4)	Control index (5)	Emission control option (6)	Control efficiency: Suppression (7)	Control efficiency: Emission control (8)	Transfer code (9)	Loading (10)	Service life (11)	Cost function (12)	Total capital investment, $: a (13)	Total capital investment, $: b x Q (14)	Cost function (15)	Annual operating cost, $: a (16)	Annual operating cost, $: b x Q (17)
T04	Tank Surface	Dilute Aq	All	3	IFR,CAds,Vent to CD	84.50		H		10	Linear	0.00	0.820	Linear	0.00	0.37
T04	Tank Surface	Org Liquid	All	3	IFR,CAds,Vent to CD	91.75		H		10	Linear	0.00	0.360	Linear	0.00	0.25
T04	Tank Surface	Org Sldg/Slurry	All	3	IFR,Cads,Vent to CD	91.50		H		10	Linear	0.00	0.360	Linear	0.00	0.27
T04	Tank Surface	2-Phase Aq/Org	All	3	IFR,Cads,Vent to CD	86.50		H		10	Linear	0.00	0.800	Linear	0.00	0.36
T04	Fugitives- Q Tank Ld	Aq Sldg/Slurry	All	5				H								
T04	Fugitives- Q Tank Ld	Dilut Aq	All	5				H								
T04	Fugitives- Q Tank Ld	Org Sldg/Slurry	All	5				H								
T04	Fugitives- Q Tank Ld	Org Liquid	All	5				H								
T04	Fugitives- Q Tank Ld	Org Sldg/Slurry	All	5				H								
D79		VOC-cont Solid		1				F								
D79		Aq Sldg/Slurry		1				F								
D79		Dilute Aq		1				F								
D79		Org Liquid		1				F								
D79		Org Sldg/Slurry		1				F								
D79				1				F								
D79		2-Phase Aq/Org		1				F								
D80	Landfill (Open)	Aq Sldg/Slurry	All	1	Earth Cover	11.00				20	Linear	0.00	0.000	Linear	0.00	2.690
D80	Landfill (Open)	Sub 7xx for 3xx	All	1	Earth Cover	11.00				20	Linear	0.00	0.000	Linear	0.00	2.690
D80	Landfill (Open)	Sub 7xx for 4xx	All	1	Earth Cover	11.00				20	Linear	0.00	0.000	Linear	0.00	2.690
D80	Landfill (Open)	Sub 7xx for 5xx	All	1	Earth Cover	11.00				20	Linear	0.00	0.000	Linear	0.00	2.690
D80	Landfill (Open)	2-Phase Aq/Org	All	1	Earth Cover	11.00				20	Linear	0.00	0.000	Linear	0.00	2.690
D80	Landfill (Open)	VOC-cont Solid	All	1	Earth Cover	11.00				0	Linear	0.00	0.000	Linear	0.00	2.690
D80	Landfill (Closed)	VOC-cont Solid	All	3	HD Cover 30 mil	0.00				30	Linear	0.00	0.760	Linear	0.00	0.030
D80	Landfill (Closed)	Aq Sldg/Slurry	All	3	HD Cover 30 mil	99.70				30	Linear	0.00	0.760	Linear	0.00	0.030
D80	Landfill (Closed)	Sub 7xx for 3xx	All	3	HD Cover 30 mil	49.30				30	Linear	0.00	0.760	Linear	0.00	0.030
D80	Landfill (Closed)	Sub 7xx for 4xx	All	3	HD Cover 30 mil	49.30				30	Linear	0.00	0.760	Linear	0.00	0.030
D80	Landfill (Closed)	Sub 7xx for 5xx	All	3	HD Cover 30 mil	49.30				30	Linear	0.00	0.760	Linear	0.00	0.030
D80	Landfill (Closed)	2-Phase Aq/Org	All	3	HD Cover 30 mil	49.30				30	Linear	0.00	0.760	Linear	0.00	0.030
D80	Landfill (Closed)	VOC-cont Solid	All	4	HD Cover 100 mil	0.00				30	Linear	0.00	1.960	Linear	0.00	0.080
D80	Landfill (Closed)	Aq Sldg/Slurry	All	4	HD Cover 100 mil	99.90				30	Linear	0.00	1.960	Linear	0.00	0.080
D80	Landfill (Closed)	Sub 7xx for 3xx	All	4	HD Cover 100 mil	84.80				30	Linear	0.00	1.960	Linear	0.00	0.080
D80	Landfill (Closed)	Sub 7xx for 4xx	All	4	HD Cover 100 mil	84.80				30	Linear	0.00	1.960	Linear	0.00	0.080
D80	Landfill (Closed)	Sub 7xx for 5xx	All	4	HD Cover 100 mil	84.80				30	Linear	0.00	1.960	Linear	0.00	0.080
D80	Landfill (Closed)	2-Phase Aq/Org	All	4	HD Cover 100 mil	84.80				30	Linear	0.00	1.960	Linear	0.00	0.080

See notes at end of table.

(continued)

TABLE D-18 (continued)

TSDF process code (1)	TSDF emission source (2)	Waste form (3)	Volatility class (4)	Control index (5)	Emission control option (6)	Control efficiency: Suppression (7)	Control efficiency: Emission control (8)	Transfer code (9)	Loading (10)	Service life (11)	Cost function (12)	Total capital investment, $: a (13)	Total capital investment, $: b x Q (14)	Cost function (15)	Annual operating cost, $: a (16)	Annual operating cost, $: b x Q (17)
D83	Fugitives- Imp Load	Aq Sldg/Slurry		1				K								
D83	Fugitives- Imp Load	Sub 2xx for 4xx		1				K								
D83	Fugitives- Imp Load	2-Phase Aq/Org		1				K								
D83	Fugitives- Imp Load	Sub 2xx for 4xx		1				K								
D83	Fugitives- Imp Load	Sub 2xx for 5xx		1				K								
FXP	Fixation Pit	Aq Sldg/Slurry	All	3			95.00			20	Linear	0.00	12.030	Linear	0.00	3.720
FXP	Fixation Pit	Sub 7xx for 3xx	All	3			95.00			20	Linear	0.00	12.030	Linear	0.00	3.720
FXP	Fixation Pit	Sub 7xx for 4xx	All	3			95.00			20	Linear	0.00	12.030	Linear	0.00	3.720
FXP	Fixation Pit	Sub 7xx for 5xx	All	3			95.00			20	Linear	0.00	12.030	Linear	0.00	3.720
FXP	Fixation Pit	2-Phase Aq/Org	All	3			95.00			20	Linear	0.00	12.030	Linear	0.00	3.720
FXP	Fixation Pit	VOC-cont Solid	All	3			95.00			20	Linear	0.00	12.030	Linear	0.00	3.720
LDA	Fugitives- LDR Incin	Aq Sldg/Slurry	All	1				E								
LDA	Fugitives- LDR Incin	Dilute Aq	All	1				E								
LDA	Fugitives- LDR Incin	Org Liquid	All	1				E								
LDA	Fugitives- LDR Incin	Org Sldg/Slurry	All	1				E								
LDA	Fugitives- LDR Incin	2-Phase Aq/Org	All	1				E								

[a]This table contains all cost-related data necessary to estimate control cost impacts with the Source Assessment Model.

[b]The definitions of columns for the TSDF Process Control File are:

1 = Management process code.
2 = Management process definition.
3 = Waste form definition.
4 = Volatility definition.
5 = Emission control numeric indicator.
6 = Emission control definition.
7 = Suppression control efficiency.
8 = Control efficiency.
9 = Letter indicator for engaging fugitive controls; refers to Table D-19, column 1, THL process indicator.
10 = Letter indicator for engaging loading controls; refers to Table D-19, column 1, THL process indicator.
11 = Service life of control equipment (yr).
12 = Cost function description, for capital investment.
13 = Fixed control cost for capital investment.
14 = Throughput multiplier for capital investment.
15 = Cost function description for annual operating cost.
16 = Fixed annual operating cost.
17 = Throughput multiplier for annual operating cost.

TABLE D-19. TRANSFER, HANDLING, AND LOAD CONTROL COST FILE USED BY THE SOURCE ASSESSMENT MODEL[a,b]

THL process indicator (1)	Emission source (2)	Waste form (3)	Volatility class (4)	Control index (5)	Emission control option (6)	Control efficiency (suppression) (7)	Service life (8)	Cost function (9)	Total capital investment, $ a (10)	Total capital investment, $ b x Q (11)	Cost function (12)	Annual operating cost a (13)	Annual operating cost b x Q (14)
A	Drum Loading	VOC-Cont Solid	All	1	Submerged Loading	65.00	15	Linear	0.00	0.49000	Linear	0.00	0.03000
A	Drum Loading	Aq Sldg/Slur	All	1	Submerged Loading	65.00	15	Linear	0.00	0.70000	Linear	0.00	0.04000
A	Drum Loading	Oil Aqueous	All	1	Submerged Loading	65.00	15	Linear	0.00	0.87000	Linear	0.00	0.04000
A	Drum Loading	Org Liquid	All	1	Submerged Loading	65.00	15	Linear	0.00	0.89000	Linear	0.00	0.05000
A	Drum Loading	Org Sldg/Slurry	All	1	Submerged Loading	65.00	15	Linear	0.00	0.64000	Linear	0.00	0.03000
A	Drum Loading	2-Phase Aq/Org	All	1	Submerged Loading	65.00	15	Linear	0.00	0.89000	Linear	0.00	0.05000
B	Truck Loading	Aq Sldg/Slur	All	1	Submerged Loading	65.00	15	Linear	0.00	0.75000	Linear	0.00	0.04000
B	Truck Loading	Oil Aqueous	All	1	Submerged Loading	65.00	15	Linear	0.00	0.92000	Linear	0.00	0.05000
B	Truck Loading	Org Liquid	All	1	Submerged Loading	65.00	15	Linear	0.00	0.94000	Linear	0.00	0.05000
B	Truck Loading	Org Sldg/Slurry	All	1	Submerged Loading	65.00	15	Linear	0.00	0.78000	Linear	0.00	0.04000
B	Truck Loading	2-Phase Aq/Org	All	1	Submerged Loading	65.00	15	Linear	0.00	0.79000	Linear	0.00	0.04000
C	Fugitives- Drum Loading	Aq Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	3.57000	Linear	918.00	0.94100
C	Fugitives- Drum Loading	Oil Aqueous	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	3.57000	Linear	918.00	0.94100
C	Fugitives- Drum Loading	Org Liquid	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	3.57000	Linear	918.00	0.94100
C	Fugitives- Drum Loading	Org Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	3.57000	Linear	918.00	0.94100
C	Fugitives- Drum Loading	2-Phase Aq/Org	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	3.57000	Linear	918.00	0.94100
D	Fugitives- Sto Tank Loading	Aq Sldg/Slur	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	1.28000	Linear	918.00	0.33700
D	Fugitives- Sto Tank Loading	Oil Aqueous	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	1.28000	Linear	918.00	0.33700
D	Fugitives- Sto Tank Loading	Org Liquid	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	1.28000	Linear	918.00	0.33700
D	Fugitives- Sto Tank Loading	Org Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	1.28000	Linear	918.00	0.33700
D	Fugitives- Sto Tank Loading	2-Phase Aq/Org	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	1.28000	Linear	918.00	0.33700
E	Fugitives- Incin Load(T03)	Aq Sldg/Slur	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	2.14040	Linear	918.00	0.56430
E	Fugitives- Incin Load(T03)	Oil Aqueous	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	2.14040	Linear	918.00	0.56430
E	Fugitives- Incin Load(T03)	Org Liquid	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	2.14040	Linear	918.00	0.56430
E	Fugitives- Incin Load(T03)	Org Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	2.14040	Linear	918.00	0.56430
E	Fugitives- Incin Load(T03)	2-Phase Aq/Org	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	2.14040	Linear	918.00	0.56430
F	Fugitives-Inj Well Load(D79)	Aq Sldg/Slur	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.11300	Linear	918.00	0.02990
F	Fugitives-Inj Well Load(D79)	Oil Aqueous	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.11300	Linear	918.00	0.02990
F	Fugitives-Inj Well Load(D79)	Org Liquid	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.11300	Linear	918.00	0.02990
F	Fugitives-Inj Well Load(D79)	Org Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.11300	Linear	918.00	0.02990
F	Fugitives-Inj Well Load(D79)	2-Phase Aq/Org	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.11300	Linear	918.00	0.02990
G	Fugitives- Aertd Treat Tank Loading	Aq Sldg/Slur	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01630	Linear	918.00	0.00430
G	Fugitives- Aertd Treat Tank Loading	Oil Aqueous	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01630	Linear	918.00	0.00430
G	Fugitives- Aertd Treat Tank Loading	2-Phase Aq/Org	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01630	Linear	918.00	0.00430

See notes at end of table.

(continued)

TABLE D-19 (continued)

THL process indicator (1)	Emission source (2)	Waste form (3)	Volatility class (4)	Control index (5)	Emission control option (6)	Control efficiency (suppression) (7)	Service life (8)	Cost function (9)	Total capital investment, $ a (10)	Total capital investment, $ b x Q (11)	Cost function (12)	Annual operating cost a (13)	Annual operating cost b x Q (14)
G	Fugitives- Aertd Treat Tank Loading	Org Liquid	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01630	Linear	918.00	0.00430
G	Fugitives- Aertd Treat Tank Loading	Org Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01630	Linear	918.00	0.00430
H	Fugitives- Osct Treat Tank Loading	Aq Sldg/Slur	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.08340	Linear	918.00	0.02200
H	Fugitives- Osct Treat Tank Loading	Oil Aqueous	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.08340	Linear	918.00	0.02200
H	Fugitives- Osct Treat Tank Loading	2-Phase Aq/Org	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.08340	Linear	918.00	0.02200
H	Fugitives- Osct Treat Tank Loading	Org Liquid	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.08340	Linear	918.00	0.02200
H	Fugitives- Osct Treat Tank Loading	Org Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.08340	Linear	918.00	0.02200
I	Fugitives- Storage Imp Loading	Aq Sldg/Slur	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.73400	Linear	918.00	0.19400
I	Fugitives- Storage Imp Loading	Oil Aqueous	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.73400	Linear	918.00	0.19400
I	Fugitives- Storage Imp Loading	2-Phase Aq/Org	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.73400	Linear	918.00	0.19400
I	Fugitives- Storage Imp Loading	Org Liquid	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.73400	Linear	918.00	0.19400
I	Fugitives- Storage Imp Loading	Org Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.73400	Linear	918.00	0.19400
J	Fugitives- Treat Imp Loading	Aq Sldg/Slur	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01130	Linear	918.00	0.00298
J	Fugitives- Treat Imp Loading	Oil Aqueous	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01130	Linear	918.00	0.00298
J	Fugitives- Treat Imp Loading	2-Phase Aq/Org	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01130	Linear	918.00	0.00298
J	Fugitives- Treat Imp Loading	Org Liquid	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01130	Linear	918.00	0.00298
J	Fugitives- Treat Imp Loading	Org Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01130	Linear	918.00	0.00298
K	Fugitives- Disp Imp Loading	Aq Sldg/Slur	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.13600	Linear	918.00	0.03580
K	Fugitives- Disp Imp Loading	Oil Aqueous	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.13600	Linear	918.00	0.03580
K	Fugitives- Disp Imp Loading	2-Phase Aq/Org	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.13600	Linear	918.00	0.03580
K	Fugitives- Disp Imp Loading	Org Liquid	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.13600	Linear	918.00	0.03580
K	Fugitives- Disp Imp Loading	Org Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.13600	Linear	918.00	0.03580
M	Fugitives- Terminal Loading	Aq Sldg/Slur	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.89200	Linear	918.00	0.23500
M	Fugitives- Terminal Loading	Oil Aqueous	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.89200	Linear	918.00	0.23500
M	Fugitives- Terminal Loading	Org Liquid	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.89200	Linear	918.00	0.23500
M	Fugitives- Terminal Loading	Org Sldg/Slurry	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.89200	Linear	918.00	0.23500
M	Fugitives- Terminal Loading	2-Phase Aq/Org	All	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.89200	Linear	918.00	0.23500

See notes at end of table.

(continued)

TABLE D-19 (continued)

THL process indicator (1)	Emission source (2)	Waste form (3)	Volatility class (4)	Control index (5)	Emission control option (6)	Control efficiency (suppression) (7)	Service life (8)	Cost function (9)	Total capital investment, $ a (10)	Total capital investment, $ b x Q (11)	Cost function (12)	Annual operating cost a (13)	Annual operating cost b x Q (14)

[a]This table contains all cost-related data necessary to estimate control cost impacts with the Source Assessment Model.

[b]The definitions of columns for the TSDF Process Control File are:

1 = Transfer, handling, and loading (THL) process indicator.
2 = Emission source.
3 = Waste form definition.
4 = Volatility definition.
5 = Emission control numeric indicator.
6 = Emission control definition.
7 = Suppression control efficiency.
8 = Service life of control equipment (yr).
9 = Cost function description, for capital investment.
10 = Fixed control cost for capital investment.
11 = Throughput multiplier for capital investment.
12 = Cost function description for annual operating cost.
13 = Fixed annual operating cost.
14 = Throughput multiplier for annual operating cost.

management unit, such as the surface area and waste retention time for surface impoundments. In general, information at that level of detail is not available for all the TSDF. For most TSDF, only the total throughput of the waste management units is known. Therefore, to estimate costs of emission control, it was necessary to derive cost functions that estimate control costs as a function of the waste management unit throughput as was done for the TSDF emission factors. The throughput data available for the TSDF waste management units are total values. For instance, for treatment surface impoundments, a particular facility may have a million gallons per day throughput; however, that could be in one large impoundment or three smaller impoundments. This lack of unit-specific information prevents rigorous determination of facility-specific emission and control cost estimates.

Although the information about the characteristics of specific waste management units is limited, there are statistical data available with which it is possible to describe certain characteristics of the units on a national basis. The Westat Survey conducted in 1981, for instance, provides considerable statistical data useful for determining the national distribution of sizes of storage tanks (storage volume), surface impoundments (surface area), and landfills (surface areas and depth). With these statistical data it is possible to generate cumulative frequency distributions of unit size characteristics. Much of these data, in fact, were the bases for the selection of the model unit sizes described in Appendix C. Each model unit has a certain waste throughput and other design and operating characteristics; multiple model units were selected for each waste management process to represent the range of sizes nationally. These model units served as the basis for the development of emission estimates as well as control costs.

The costs for controls applied to the model units were developed and the relationship of control cost to throughput was computed for each of the model units. Because there are no data to determine which of the model unit sizes most closely matches a management process in a particular facility, a method of assigning the model unit costs (and emissions) to each waste management unit in each TSDF, nationally, was needed. To this

end, a national average model unit was defined from the statistical information on TSDF management units. Each model unit size was assumed to represent a certain portion of the nationwide cumulative frequency distribution curve for that particular management process. The weighting factor for each management process model unit is the percentage of the cumulative frequency for that model unit. The weighted costs per megagram of waste throughput were then determined by multiplying the weighting factor by the total capital investment and annual operating cost for the corresponding model unit. These weighted costs were compiled for each management process to constitute the control cost file used as input to the SAM. This methodology for developing weighted control cost factors is the same as that used for emission factor determinations and is an approximation of the effects of economy-of-scale on nationwide control cost estimates.

D.2.6 Test Method Conversion Factor File

An important aspect of any pollution control strategy applied to TSDF involves identifying those hazardous waste streams that require control. One means of accomplishing this is to establish control levels based on the emission potential of the waste entering a particular management process. Several test methods have been evaluated to quantify emission potential; these are discussed in Appendix G. The test method selected to measure the waste stream emission potential, which has been defined as the VO content of the waste, is steam distillation with 20 percent (by volume) of the waste distilled for analysis. In general, the VO test method results are a function of the volatility of individual compounds because the amount of a particular waste constituent removed from the waste sample and recovered for analysis depends largely on volatility. The test method results in essentially 100 percent removal and a high distillate recovery for the most volatile compounds in the waste; the removal and recovery of less volatile and more water soluble compounds are less than 100 percent. With a VO test method established, the VO content of a hazardous waste can be measured and then compared to the limits on VO content, established as part of a control strategy, to determine if emission controls are required for the specific waste stream.

Test method conversion factors were developed, based on laboratory test data, to allow the SAM to simulate the VO test method numerically to obtain VO measurements similar to those found in the laboratory. In this

way the SAM can determine what waste streams in the data base would be controlled for different VO action levels (waste VO concentration above which controls must be applied to units managing that waste) and, as a result, define the affected population of wastes for a given control strategy. For example, the waste data base used in the SAM contains concentrations of specific compounds in specific waste streams. These compounds are assigned a surrogate designation on the basis of their volatility. The test method conversion factors are applied to each type of surrogate to estimate how much of the surrogate would be removed by the test method and contribute to the total measured VO. The contribution of each surrogate is then summed for the waste to estimate the VO content that the test method would measure. The only use of the test method conversion factors is to estimate (from the data base on waste compositions) what the test method would measure as the VO content of a waste stream. This estimated VO content is compared to the VO concentration limits to determine whether a specific waste stream would be controlled under a given VO action level. The regulated wastes that are identified for control are used in the SAM to determine the nationwide impacts of the given VO action level within a control strategy.

In the development of the conversion factors, several synthetic wastes containing nine select compounds, which represent a wide range of volatilities, were evaluated for percent recovery using the test method. The compounds were present in different types of waste matrices that included aqueous, organic, solids, and combinations of the three. The recovery of these different compounds in different synthetic waste matrices forms the basis for the test method conversion factors. Appendix G contains the details regarding test method development.

The approach was to assign each of the nine synthetic waste compounds to its corresponding SAM volatility class based on vapor pressure and Henry's law constant. The normalized percent recovery was used to adjust for recoveries that were either greater than or less than 100 percent. The normalized recovery for each compound in a given volatility class was averaged to provide a single conversion factor for each class. The results are summarized in Table D-20 for each volatility class and type of waste matrix. The results indicate that the method should remove all of the

TABLE D-20. SUMMARY OF TEST METHOD CONVERSION FACTORS[a]

Volatility class	Waste matrix		
	Aqueous	Organic	Solid
Very high	NA	1.0[b]	1.0[b]
High	1.0	1.0	1.0
Moderate	1.0	0.3	0.5
Low	0.2	0[c]	0[c]

NA = Not applicable.

[a]This table presents factors that, when multiplied by the concentration of a specific volatility class in the waste, provide an estimate of the volatile organic content that the test method would measure for the waste.

[b]Assumes that the test method will remove all of the highly volatile gases from the waste.

[c]Assumes that because of the very low vapor pressure for this category ($<1.33 \times 10^{-4}$ kPa) the test method will remove very little from the waste.

highly volatile compounds from the waste. All of the moderately volatile compounds in an aqueous matrix are expected to be removed; however, only 30 to 50 percent of the moderately volatile compounds (conversion factors of 0.3 to 0.5) in an organic or solid matrix are expected to be recovered by the method.

A headspace analysis was also investigated as an alternative procedure for covered tanks because emissions from this source are more directly related to the vapor phase concentration than to the total VO content measured by steam distillation. For the headspace analysis, a conversion factor was also necessary to estimate the vapor phase concentration that the headspace method would measure from a known waste composition. The vapor phase concentration is to be expressed in kilopascals for comparison with existing regulations for storage tanks.

The conversion factors for the headspace method are given in Table D-21. When these factors are multiplied by the concentration in the waste (expressed as weight fraction) for each volatility class, the sum of the results for each class is an estimate of what the headspace methods would measure. These factors were derived from the synthetic waste studies, and each factor is the average from all compounds that are grouped in a given volatility class and waste matrix.

The headspace conversion factors are used with the waste compositions in the SAM's data base to estimate what the headspace method would measure for a given waste stream. The predicted method results are then compared to VO concentration limits for storage tanks to determine whether controls are required. This approach defines the population of controlled wastes, which is used in the SAM to determine the nationwide impacts for controlling covered tanks.

D.2.7 Incidence and Risk File

Health risks posed by exposure to TSDF air emissions typically are presented in two forms: annual cancer incidence (incidents per year nationwide resulting from exposure to TSDF air emissions) and maximum lifetime risk (the highest risk of contracting cancer that any individual could have from exposure to TSDF emissions over a 70-year lifetime). These two health risk forms are used as an index to quantify health impacts related to TSDF emission controls. Detailed discussions on the development of health impacts data are found in Appendixes E and J.

TABLE D-21. SUMMARY OF HEADSPACE CONVERSION FACTORS TO OBTAIN KILOPASCALS (kPa)[a]

Volatility class	Waste matrix		
	Aqueous[b]	Organic	Solid
High	441	24.8	3.93
Medium	26.2	5.10	0.09
Low	3.520	0	0

[a]This table presents conversion factors that are multiplied by the concentration (as weight fraction) of the volatility class in a waste to estimate what the headspace method would measure for that class. For example, with an organic waste containing only medium volatiles at a level of 0.1 weight fraction (10 percent), the headspace method results are estimated as 0.1 x 5.1 = 0.51 kPa.

[b]The results for aqueous wastes are capped by the vapor pressure of the waste constituent surrogate compound (i.e., if the predicted method results exceed the surrogates' vapor pressure, then the vapor pressure should be used as the method measurement).

The Human Exposure Model (HEM) provided the basis in the SAM for estimating annual cancer incidence and risk to the maximum exposed individual due to TSDF-generated airborne hazardous wastes. The HEM is a computer model that calculates exposure levels for a population within 50 km of a facility using 1980 census population distributions and local (site-specific) meteorological data. The HEM was run for each TSDF using a unit risk factor of 1 and a facility emission rate of 10,000 kg/yr. The HEM results were then compiled into risk and incidence files that can be adjusted to reflect the level of actual emissions resulting from implementation of a particular control strategy. The site-specific HEM incidence and risk values are adjusted within the SAM by the ratio of annual facility emissions to 10,000 kg and by the TSDF unit risk factor to give facility-specific estimates for the control strategy under consideration. Individual dual facility incidences are summed to give the nationwide TSDF incidence value.

D.3 OUTPUT FILES

The SAM was developed to generate data necessary for comparison of various TSDF control options in terms of their nationwide environmental, health, economic, and energy impacts. Therefore, emissions (controlled and uncontrolled), costs (capital, annual operating, and annualized), and health impacts (annual cancer incidence and maximum risk) that represent impacts on a national scale are the primary outputs of interest. In addition, the SAM was designed to provide data that could be stored and summarized in a number of ways.

Through manipulation of the SAM post-processor, emissions can be summed and presented by management process (e.g., nationwide emissions for all open storage impoundments), and by source (e.g., nationwide emissions from process losses, spills, or transfer and handling). On a nationwide basis, the emission and cost data are also available for each waste code, for each waste form, and for each constituent within a waste. Emission and cost data are required at this level of detail for comparison and evaluation of the various control strategies being examined. Health impacts, however, are expressed in terms of overall nationwide risk or cancer incidences. In this document, the SAM outputs are presented in Chapters 3.0 (uncontrolled emissions by source category), 6.0 (emission,

incidence, and risk reductions for the example control strategies), and 7.0 (capital and annual costs associated with the control strategies).

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APPENDIX E

ESTIMATING HEALTH EFFECTS

APPENDIX E

ESTIMATING HEALTH EFFECTS

Many adverse health effects can result from exposure to air emissions from hazardous waste treatment, storage, and disposal facilities (TSDF). The major pathways for human exposure to environmental contaminants are through inhalation, ingestion, or dermal contact. Airborne contaminants may be toxic to the sites of immediate exposure, such as the skin, eyes, and linings of the respiratory tract. Toxicants may also cause a spectrum of systemic effects following absorption and distribution to various target sites such as the liver, kidneys, and central nervous system.

Exposure to contaminants in air can be acute, subchronic, or chronic. Acute exposure refers to a very short-term (i.e., $\leq$24 h), usually single-dose, exposure to a contaminant. Health effects often associated with acute exposure include: central nervous system effects such as headaches, drowsiness, anesthesia, tremors, and convulsions; skin, eye, and respiratory tract irritation; nausea; and olfactory effects such as awareness of unpleasant or disagreeable odors. Many of these effects are reversible and disappear with cessation of exposure. Acute exposure to very high concentrations or to low levels of highly toxic substances can, however, cause serious and irreversible tissue damage, and even death. A delayed toxic response may also occur following acute exposure to certain agents.

Chronic exposures are those that occur for long periods of time (from many months to several years). Subchronic exposure falls between acute and chronic exposure, and usually involves exposure for a period of weeks or months. Generally, the health effects of greatest concern following intermittent or continuous long-term exposures are those that cause either irreversible damage and serious impairment to the normal functioning of the individual, such as cancer and organ dysfunctions, or death.

The risk associated with exposure to a toxic agent is a function of many factors, including the physical and chemical characteristics of the substance, the nature of the toxic response and the dose required to produce the effect, the susceptibility of the exposed individual, and the exposure situation. In many cases, individuals may be concurrently or sequentially exposed to a mixture of compounds, which may influence the risk by changing the nature and magnitude of the toxic response.

E.1 ESTIMATION OF CANCER POTENCY

The unit risk estimate (URE, unit risk factor) is used by the Environmental Protection Agency (EPA) in its analysis of carcinogens. It is defined as the lifetime cancer risk occurring in a hypothetical population in which all individuals are exposed throughout their lifetime (assumed to be 70 years) to an average concentration of 1 $\mu g/m^3$ of the pollutant in the air they breathe. Unit risk estimates can be used for two purposes: (1) to compare the carcinogenic potency of several agents with one another, and (2) to give a rough indication of the public health risk that might be associated with estimated air exposure to these agents.[1]

In the development of unit risk estimates, EPA assumes that if experimental data show that a substance is carcinogenic in animals, it may also be carcinogenic in humans. The EPA also assumes that any exposure to a carcinogenic substance poses some risk.[2] This nonthreshold presumption is based on the view that as little as one molecule of a carcinogenic substance may be sufficient to transform a normal cell into a cancer cell. Exposed individuals are represented by a referent male having a standard weight, breathing rate, etc. (no reference is made to factors such as race or state of health).

The data used for the quantitative estimate can be of two types: (1) lifetime animal studies, and (2) human studies where excess cancer risk has been associated with exposure to the agent. It is assumed, unless evidence exists to the contrary, that if a carcinogenic response occurs at the dose levels used in a study, then responses will occur at all lower doses with an incidence determined by the extrapolation model.

There is no solid scientific basis for any mathematical extrapolation model that relates carcinogen exposure to cancer risks at the extremely low

concentrations that must be dealt with in evaluating environmental hazards. For practical reasons, such low levels of risk cannot be measured directly either by animal experiments or by epidemiologic studies. We must, therefore, depend on our current understanding of the mechanisms of carcinogenesis for guidance as to which risk model to use. At present, the dominant view of the carcinogenic process is that most agents that cause cancer also cause irreversible damage to DNA. This position is reflected by the fact that a very large proportion of agents that cause cancer are also mutagenic. There is reason to expect that the quantal type of biological response, which is characteristic of mutagenesis, is associated with a linear nonthreshold dose-response relationship. Indeed, there is substantial evidence from mutagenesis studies with both ionizing radiation and a wide variety of chemicals that this type of dose-response model is the appropriate one to use. This is particularly true at the lower end of the dose-response curve. At higher doses, there can be an upward curvature probably reflecting the effects of multistage processes on the mutagenic response. The linear nonthreshold dose-response relationship is also consistent with the relatively few epidemiologic studies of cancer responses to specific agents that contain enough information to make the evaluation possible (e.g., radiation-induced leukemia, breast and thyroid cancer, skin cancer induced by arsenic in drinking water, liver cancer induced by aflatoxins in the diet). There is also some evidence from animal experiments that is consistent with the linear nonthreshold model (e.g., liver tumors induced in mice by 2-acetylaminofluorene in the large-scale ED_{01} study at the National Center for Toxicological Research and the initiation stage of the two-stage carcinogenesis model in rat liver and mouse skin).

Because of this evidence, the linear nonthreshold model is considered to be a viable model for any carcinogen, and unless there is direct evidence to the contrary, it is used as the primary basis for risk extrapolation to low levels of exposure.[3]

The mathematical formulation chosen to describe the linear nonthreshold dose-response relationship at low doses is the linearized multistage model. The linearized multistage model is applied to the original

unadjusted animal data. Risk estimates produced by this model from the animal data are then scaled to a human equivalent estimate of risk. This is done by multiplying the estimates by several factors to adjust for experiment duration, species differences, and, if necessary, route conversion. The conversion factor for species differences is currently based on models for equitoxic dose.[4] The unit risk values estimated by this method provide a plausible, upperbound limit on public risk at lower exposure levels if the exposure is accurately quantified; i.e., the true risk is unlikely to be higher than the calculated level and could be substantially lower.

The method that has been used in most of the EPA's quantitative risk assessments assumes dose equivalence in units of mg/body weight$^{2/3}$ for equal tumor response in rats and humans. This method is based on adjustment for metabolic differences. It assumes that metabolic rate is roughly proportional to body surface areas and that surface area is proportional to 2/3 power of body weight (as would be the case for a perfect sphere). The estimate is also adjusted for lifetime exposure to the carcinogen considering duration of experiment and animal lifetime.[5,6]

For unit risk estimates for air, animal studies using exposure by inhalation are preferred. When extrapolating results from the inhalation studies to humans, consideration is given to the following factors:

- The deposition of the inhaled compound throughout the respiratory tract
- Retention half-time of the inhaled particles
- Metabolism of the inhaled compound
- Differences in sites of tumor induction.

Unit risk estimation from animal studies is only an approximate indication of the actual risk in populations exposed to known concentrations of a carcinogen. Differences between species (lifespan, body size, metabolism, immunological responses, target site susceptibility), as well as differences within species (genetic variation, disease state, diet), can cause actual risk to be much different. In human populations, variations occur in genetic constitution, diet, living environment, and activity

patterns. Some populations may demonstrate a higher susceptibility due to certain metabolic or inherent differences in their response to the effects of carcinogens. Also, unit risk estimates are based on exposure to a referent adult male. There may be an increased risk with exposure to fetuses, children, or young adults. Finally, humans are exposed to a variety of compounds, and the health effects, either synergistic, additive, or antagonistic, of exposure to complex mixtures of chemicals are not known.[7,8]

E.1.1 EPA Unit Risk Estimates

The EPA has developed unit risk estimates for about 71 compounds that are either known or suspect carcinogens and that could be present at a TSDF (Table E-1). Constituents were drawn from the Agency's final rule on the identification and listing of hazardous waste (Appendix VIII)[9] and from the Industry Studies Data Base, a hazardous waste data base developed by EPA's Office of Solid Waste.[10] The unit risk estimates in Table E-1 have been derived by the Agency's Carcinogen Assessment Group,[11] and most have been verified by the Agency's Carcinogen Risk Assessment Verification Enterprise (CRAVE) or are under CRAVE review. As shown in Table E-1, these estimates range in value from 4.7×10^{-7} $(\mu g/m^3)^{-1}$ for methylene chloride to 3.3×10^{-5} $(pg/m^3)^{-1}$ for dioxin.

E.1.2 Composite Unit Risk Estimate

To estimate the cancer potency of TSDF air emissions, a composite unit risk estimate approach was adopted to address the problem of dealing with the large number of toxic chemicals that are present at TSDF. Using a composite estimate rather than individual unit risk estimates simplifies the risk assessment so that calculations do not need to be performed for each chemical emitted. The composite risk estimate is combined with estimates of ambient concentrations of total volatile organics and population exposure to estimate the additional cancer incidence in the general population and the maximum individual risk due to TSDF emissions.

Because detailed emission estimates are available and because cancer incidence and maximum individual risk are proportional to both the unit

TABLE E-1. TSDF CARCINOGEN LIST

	Constituent	Unit risk estimate $(\mu g/m^3)^{-1}$	Basis[a]
1.	acetaldehyde (75-07-0)	2.2×10^{-6}	CRAVE verified (class B2)
2.	acrylamide (79-06-1)	1.1×10^{-3}	CAG URE (class B2)
3.	acrylonitrile (107-13-1)	6.8×10^{-5}	CRAVE verified URE (class B1)
4.	aldrin (309-00-2)	4.9×10^{-3}	CRAVE verified URE (class B2)
5.	aniline (62-53-3)	7.4×10^{-6}	CAG URE (class C)
6.	arsenic (7440-38-2)	4.3×10^{-3}	CRAVE verified (class A)
7.	benz(a)anthracene (56-55-3)	8.9×10^{-4}	CAG URE (class B2)
8.	benzene (71-43-2)	8.3×10^{-6}	CRAVE verified (class A)
9.	benzidine (92-87-5)	6.7×10^{-2}	CRAVE verified URE (class A)
10.	benzo(a)pyrene (50-32-8)	1.7×10^{-3}	CAG URE (class B2)
11.	beryllium (7440-41-7)	2.4×10^{-3}	CAG URE (class B2)
12.	bis(chloroethyl) ether (111-44-4)	3.3×10^{-4}	CRAVE verified URE (class B2)
13.	bis(chloromethyl) ether (542-88-1)	2.7×10^{-3}	CAG URE (class A)
14.	1,3-butadiene (106-99-0)	2.8×10^{-4}	CRAVE verified URE (class B2)
15.	cadmium (7440-43-9)	1.8×10^{-3}	CRAVE verified URE (class B1)

(continued)

TABLE E-1 (continued)

	Constituent	Unit risk estimate, $(\mu g/m^3)^{-1}$	Basis[a]
16.	carbon tetra-chloride (56-23-5)	1.5×10^{-5}	CRAVE verified URE (class B2)
17.	chlordane (12789-03-6)	3.7×10^{-4}	CRAVE verified URE (class B2)
18.	chloroform (67-66-3)	2.3×10^{-5}	CRAVE verified (class B2)
19.	chloromethane (74-87-3)	3.6×10^{-6}	ECAO URE (class C)
20.	chloromethyl methyl ether (107-30-2)	2.7×10^{-3}	CAG URE (class A)
21.	chromium VI (7440-47-3)	1.2×10^{-2}	CRAVE verified URE (class A)
22.	DDT (50-29-3)	9.7×10^{-5}	CRAVE verified URE (class B2)
23.	dibenz(a,h) anthracene (53-70-3)	1.4×10^{-2}	CAG URE (class B2)
24.	1,2-dibromo-3-chloropropane (96-12-8)	6.3×10^{-3}	CAG URE (class B2)
25.	1,2-dichloroethane (107-06-2)	2.6×10^{-5}	CRAVE verified URE (class B2)
26.	1,1-dichloro-ethylene (75-35-4)	5.0×10^{-5}	CRAVE verified URE (class C)
27.	dieldrin (60-57-1)	4.6×10^{-3}	CRAVE verified URE (class B2)
28.	2,4-dinitrotoluene (121-14-2)	8.8×10^{-5}	CAG URE (class B2)

(continued)

TABLE E-1 (continued)

	Constituent	Unit risk estimate, $(\mu g/m^3)^{-1}$	Basis[a]
29.	1,4-dioxane (123-91-1)	1.4×10^{-6}	CAG URE (class B2)
30.	1,2-diphenylhydrazine (122-66-7)	2.2×10^{-4}	CRAVE verified (class B2)
31.	epichlorohydrin (106-89-8)	1.2×10^{-6}	CRAVE verified URE (class B2)
32.	ethylene dibromide (106-93-4)	2.2×10^{-4}	CRAVE verified URE (class B2)
33.	ethylene oxide (75-21-8)	1.0×10^{-4}	CAG URE (class B1-B2)
34.	formaldehyde (50-00-0)	1.3×10^{-5}	CAG URE (class B1)
35.	gasoline (8006-61-9)	6.6×10^{-7}	CAG URE (class B2)
36.	heptachlor (76-44-8)	1.3×10^{-3}	CRAVE verified URE (class B2)
37.	heptachlor epoxide (1024-57-3)	2.6×10^{-3}	CRAVE verified URE (class B2)
38.	hexachlorobenzene (118-74-1)	4.9×10^{-4}	CAG URE (class B2)
39.	hexachlorobutadiene (87-68-3)	2.2×10^{-5}	CRAVE verified URE (class C)
40.	hexachlorocyclohexane (no CAS #)	5.4×10^{-4}	CRAVE verified URE (class B2)
41.	alpha-hexachloro-cyclohexane (319-84-6)	1.8×10^{-3}	CRAVE verified URE (class B2)
42.	beta-hexachloro-cyclohexane (319-85-7)	5.3×10^{-4}	CRAVE verified URE (class B2)

(continued)

TABLE E-1 (continued)

	Constituent	Unit risk estimate, $(\mu g/m^3)^{-1}$	Basis[a]
43.	gamma-hexachloro-cyclohexane (lindane)(58-89-9)	3.8×10^{-4}	CRAVE verified URE (class C)
44.	hexachlorodibenzo-p-dioxin,1:2 mixture (57653-85-7 or 19408-74-3)	1.3×10^{0}	CRAVE verified URE (class B2)
45.	hexachloroethane (67-72-1)	4.0×10^{-6}	CRAVE verified URE (class C)
46.	hydrazine (302-01-2)	2.9×10^{-3}	CAG URE (class B2)
47.	3-methylcholanthrene (56-49-5)	2.7×10^{-3}	CAG URE (class B2)
48.	4,4'-methylene-bis (2-chloroaniline) (101-14-4)	4.7×10^{-5}	CAG URE (class B2)
49.	methylene chloride (75-09-2)	4.7×10^{-7}	CAG URE UCR (class B2)
50.	methyl hydrazine (60-34-4)	3.1×10^{-4}	ECAO URE (class B2)
51.	nickel refinery dust (7440-02-0)	2.4×10^{-4}	CRAVE verified URE (class A)
52.	nickel subsulfide (12035-72-2)	4.8×10^{-4}	CRAVE verified URE (class B2)
53.	2-nitropropane (79-46-9)	2.7×10^{-3}	CAG URE (class B2)
54.	n-nitrosodi-n-butylamine (924-16-3)	1.6×10^{-3}	CRAVE verified URE (class B2)
55.	n-nitroso-diethylamine (55-18-5)	4.3×10^{-2}	CRAVE verified URE (class B2)

(continued)

TABLE E-1 (continued)

	Constituent	Unit risk estimate, $(\mu g/m^3)^{-1}$	Basis[a]
56.	n-nitroso-dimethylamine (62-75-9)	1.4×10^{-2}	CRAVE verified URE (class B2)
57.	n-nitroso-n-methylurea (684-93-5)	8.6×10^{-2}	CAG URE (class B2)
58.	n-nitroso-pyrrolidine (930-55-2)	6.1×10^{-4}	CRAVE verified URE (class B2)
59.	pentachloronitro-benzene (82-68-8)	7.3×10^{-5}	CAG URE (class C)
60.	polychlorinated biphenyls (1336-36-3)	1.2×10^{-3}	CAG URE (class B2)
61.	pronamide (23950-58-5)	4.6×10^{-6}	CAG URE (class C)
62.	reserpine (50-55-5)	3.0×10^{-3}	CAG URE (class B2)
63.	2,3,7,8-tetrachloro-dibenzo-p-dioxin (1746-01-6)	3.3×10^{-5} $(pg/m^3)^{-1}$	CAG URE (class B2)
64.	1,1,2,2-tetra-chloroethane (79-34-5)	5.8×10^{-5}	CRAVE verified URE (class C)
65.	tetrachloroethylene (127-18-4)	5.8×10^{-7}	CAG URE (class B2)
66.	thiourea (62-56-6)	5.5×10^{-4}	CAG URE (class B2)
67.	toxaphene (8001-35-2)	3.2×10^{-3}	CRAVE verified URE (class B2)

(continued)

TABLE E-1 (continued)

	Constituent	Unit risk estimate, $(\mu g/m^3)^{-1}$	Basis[a]
68.	1,1,2-trichloroethane (79-00-5)	1.6×10^{-5}	CRAVE verified URE (class C)
69.	trichloroethylene (79-01-6)	1.7×10^{-6}	CAG URE (class B2)
70.	2,4,6-trichlorophenol (88-06-2)	5.7×10^{-6}	CRAVE verified URE (class B2)
71.	vinyl chloride (75-01-4)	4.1×10^{-6}	CAG URE (class A)

( ) = Chemical Abstracts Service (CAS) Number.

[a]Cancer unit risk estimates (UREs) were either (1) verified by the Carcinogen Risk Assessment Verification Enterprise (CRAVE) work group or (2) established by the Carcinogen Assessment Group (CAG), but not yet verified by CRAVE. The unit risk estimates for chloromethane and methyl hydrazine were derived by the Environmental Criteria and Assessment Office (ECAO).

Note: The constituents on this list and the corresponding unit risk estimates are subject to change.

risk estimates and emissions, an emission-weighted averaging technique was used. In calculating the emission-weighted average, the emission estimate for a compound is multiplied by the unit risk estimate for that compound. The emission-weighted arithmetic average is computed as follows:

$$\overline{RE} = \frac{\sum_{i=1}^{N} (RE_i \bullet ER_i)}{ER_t} , \qquad \text{(E-1)}$$

where

$\overline{RE}$ = weighted average unit risk estimate

RE_i = unit risk estimate for compound i

ER_i = emission rate for compound i

ER_t = total emissions for TSDF.

Using this type of average would give the same result as calculating the risk for each chemical involved.

The calculation of the composite unit risk estimate for the baseline is illustrated in Table E-2. The table lists the compounds included in the development of the composite risk estimate, total nationwide baseline emissions by compound, the unit risk estimate by compound, and the weighted-average unit risk estimate. Table E-2 shows that dioxin is included in the composite unit risk estimate. Comments were received that questioned the validity of including dioxin in the computation of the composite unit risk factor.[25] Questions were also raised about the sources of dioxin.

Dioxin is present in a listed RCRA hazardous waste, K099. Three commercial waste management facilities in the TSDF industry profile indicated they manage RCRA waste code K099. These three facilities are located in three States and manage a total of 4,500 Mg/yr of dioxin-containing wastes. The estimated emissions are produced by several treatment and storage sources. Other dioxin-containing wastes (F020, F021, F023, F026, F027, and F028) were listed after the waste data base was developed and are not included in the current TSDF industry profile. Therefore, there is reason to believe there are other facilities managing such wastes for which

TABLE E-2. CALCULATION OF THE EMISSIONS-WEIGHTED COMPOSITE UNIT RISK ESTIMATE (URE) FOR THE BASELINE[a]

Compound	Baseline emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
Acetaldehyde	1,280	2.2E-06	1.6E-09
Acrylamide	74	1.1E-03	4.5E-08
Acrylonitrile	18,000	6.8E-05	6.7E-07
Aldrin	33	4.9E-03	9.1E-08
Aniline	5,400	7.4E-06	2.2E-08
Benzene	6,100	8.3E-06	2.8E-08
Benzo(a)pyrene	1	1.7E-03	9.5E-10
Benz(a)anthracene	0.20	8.9E-04	9.9E-11
bis(chloromethyl)ether	370	2.7E-03	5.6E-07
bis(2-chloroethyl)ether	2.4	3.3E-04	4.4E-10
Butadiene(1,3)	110	2.8E-04	1.7E-08
Carbon tetrachloride	16,000	1.5E-05	1.4E-07
Chlordane	7.3	3.7E-04	1.5E-09
Chloroform	4,000	2.3E-05	5.2E-08
Chloromethane	58	3.6E-06	1.2E-10
Chloromethyl(methyl)ether	0	2.7E-03	0.0E+00
DDT (4,4')	27	9.7E-05	1.5E-09
Dibenz(a,h)anthracene	0.05	1.4E-02	4.2E-10
Dibromo-(1,2)-chloropropane(3)	1.1	6.3E-03	3.9E-09
Dibromoethane	0	2.2E-04	0.0E+00
Dichloroethane(1,2)	21,000	2.6E-05	3.1E-07
Dichloroethylene(1,1)	1,100	5.0E-05	3.1E-08
Dinitrotoluene(2,4)	240	8.8E-05	1.2E-08
Dioxane(1,4)	250	1.4E-06	2.0E-10
Diphenylhydrazine(1,2)	0.70	2.2E-04	8.6E-10
Epichlorohydrin	1,600	1.2E-06	1.1E-09
Ethylene dibromide	7.2	2.2E-04	8.8E-10
Ethyleneoxide	0	1.0E-04	0.0E+00
Formaldehyde	2,400	1.3E-05	1.8E-08
Gasoline	2,700	6.6E-07	9.8E-10
Heptachlor	1.2	1.3E-03	8.7E-10
Hexachlorobenzene	160	4.9E-04	4.3E-08
Hexachlorobutadiene	46,000	2.2E-05	5.6E-07
Hexachloroethane	1,100	4.0E-06	2.5E-09
Hydrazine	230	2.9E-03	3.7E-07
Lindane	9.1E-05	3.8E-04	1.9E-14
Methyl hydrazine	3.6	3.1E-04	6.2E-10
Methylcholanthrene(3)	4.7	2.7E-03	7.1E-09
Methylene chloride	15,000	4.7E-07	4.0E-09
Nitropropane(2)	5.2	2.7E-03	7.8E-09

(continued)

TABLE E-2 (continued)

Compound	Baseline emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
N-Nitrosopyrrolidine	0	6.1E-04	0.0E+00
N-nitroso-n-methylurea	0	8.6E-02	0.0E+00
Polychlorinated biphenyls	0.05	1.2E-03	3.2E-11
Tetrachlorodibenzo(2,3,7,8)-p-dioxin	0.31	3.3E+01	5.7E-06
Tetrachloroethane(1,1,2,2)	6,200	5.8E-05	2.0E-07
Tetrachloroethylene	16,000	5.8E-07	5.1E-09
Thiourea	2.0	5.5E-04	6.1E-10
Toxaphene	56	3.2E-03	1.0E-07
Trichloroethane(1,1,2)	16,000	1.6E-05	1.4E-07
Trichloroethylene	52,000	1.7E-06	4.9E-08
Trichlorophenol(2,4,6)	30	5.7E-06	9.6E-11
Vinyl chloride	620	4.1E-06	1.4E-09
Total nationwide baseline emissions	1,790,000		9.2×10^{-6}

TSDF = Treatment, storage, and disposal facility.

[a]This table illustrates the calculation of the composite unit risk estimate for the baseline.

[b]Units are $(\mu g/m^3)^{-1}$.

there are no emission estimates. For these reasons, it is appropriate to include dioxin in the computation of the composite unit risk factor.

When dioxin is included in the calculation, a composite unit risk estimate of 9.2×10^{-6} $(\mu g/m^3)^{-1}$ results. Without dioxin, a unit risk estimate of 3.5×10^{-6} $(\mu g/m^3)^{-1}$ is calculated. The composite unit risk estimate used in this analysis for the baseline is 9.2×10^{-6} $(\mu g/m^3)^{-1}$. This calculation was repeated for each of the control options described in Chapter 5.0 based on the compound-specific emission estimates associated with the option. The resulting composite unit risk estimates for control options 1 through 5 were 1.2×10^{-5}, 1.3×10^{-5}, 1.1×10^{-5}, 1.4×10^{-5}, and 1.2×10^{-5} $(\mu g/m^3)^{-1}$, respectively.[12] The slight difference among these values reflects minor changes in the emission rates of specific compounds under the various control options. The calculations for the control options are illustrated in Tables E-3 through E-7.

In addition to the uncertainties in estimates of emissions, other difficulties arise in averaging the UREs for specific constituents to develop a composite URE. Unit risk estimates have not been developed for all of the pollutants of concern, due, in part, to insufficient data. Various options for dealing with this problem were considered. The EPA selected an approach in which only those carcinogens for which unit risk estimates were available would be included in the analysis of cancer risk. Consideration was also given to adding the weighted risk estimates for only those compounds having similar EPA classifications,[13] i.e., to present the composite unit risk estimate and associated cancer risks separately for Group A compounds (human carcinogens), Group B compounds (probable human carcinogens), and Group C compounds (possible human carcinogens). However, because only about 1 percent of the weighted composite risk estimate is attributed to Group A compounds and about 5 percent for Group C, EPA elected to present the risk associated with all three groups combined.

E.2 DETERMINING NONCANCER HEALTH EFFECTS

Although cancer is of great concern as an adverse health effect associated with exposure to a chemical or a mixture of chemicals, many other health effects may be associated with such exposures. These effects may range from subtle biochemical, physiological, or pathological effects

TABLE E-3. CALCULATION OF THE EMISSIONS-WEIGHTED COMPOSITE UNIT RISK ESTIMATE (URE) FOR CONTROL OPTION 1[a]

Compound	Option 1 emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
Acetaldehyde	85	2.2E-06	2.0E-09
Acrylamide	2.3	1.1E-03	2.8E-08
Acrylonitrile	1,200	6.8E-05	8.8E-07
Aldrin	33	4.9E-03	1.7E-06
Aniline	26	7.4E-06	2.0E-09
Benzene	270	8.3E-06	2.4E-08
Benzo(a)pyrene	0.92	1.7E-03	1.7E-08
Benz(a)anthracene	0.01	8.9E-04	9.6E-11
bis(chloromethyl)ether	17	2.7E-03	5.0E-07
bis(2-chloroethyl)ether	0.13	3.3E-04	4.6E-10
Butadiene(1,3)	6.7	2.8E-04	2.0E-08
Carbon tetrachloride	770	1.5E-05	1.2E-07
Chlordane	5.4	3.7E-04	2.1E-08
Chloroform	150	2.3E-05	3.7E-08
Chloromethane	4.3	3.6E-06	1.7E-10
Chloromethyl(methyl)ether	0	2.7E-03	0.0E+00
DDT (4,4')	27	9.7E-05	2.8E-08
Dibenz(a,h)anthracene	0	1.4E-02	0.0E+00
Dibromo-(1,2)-chloropropane(3)	0.02	6.3E-03	1.4E-09
Dibromoethane	0	2.2E-04	0.0E+00
Dichloroethane(1,2)	790	2.6E-05	2.2E-07
Dichloroethylene(1,1)	56	5.0E-05	3.0E-08
Dinitrotoluene(2,4)	7.7	8.8E-05	7.3E-09
Dioxane(1,4)	10	1.4E-06	1.5E-10
Diphenylhydrazine(1,2)	0.11	2.2E-04	2.6E-10
Epichlorohydrin	70	1.2E-06	9.0E-10
Ethylene dibromide	0.55	2.2E-04	1.3E-09
Ethyleneoxide	0	1.0E-04	0.0E+00
Formaldehyde	220	1.3E-05	3.1E-08
Gasoline	130	6.6E-07	9.6E-10
Heptachlor	0.06	1.3E-03	8.4E-10
Hexachlorobenzene	4.7	4.9E-04	2.5E-08
Hexachlorobutadiene	2,400	2.2E-05	5.6E-07
Hexachloroethane	7.3	4.0E-06	3.1E-10
Hydrazine	19	2.9E-03	6.0E-07
Lindane	0	3.8E-04	0.0E+00
Methyl hydrazine	0.30	3.1E-04	1.0E-09
Methylcholanthrene(3)	4.7	2.7E-03	1.4E-07
Methylene chloride	510	4.7E-07	2.6E-09
Nitropropane(2)	0.26	2.7E-03	7.5E-09

(continued)

TABLE E-3 (continued)

Compound	Option 1 emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
N-Nitrosopyrrolidine	0	6.1E-04	0.0E+00
N-nitroso-n-methylurea	0	8.6E-02	0.0E+00
Polychlorinated biphenyls	0	1.2E-03	0.0E+00
Tetrachlorodibenzo(2,3,7,8)-p-dioxin	0.02	3.3E+01	7.1E-06
Tetrachloroethane(1,1,2,2)	26	5.8E-05	1.6E-08
Tetrachloroethylene	650	5.8E-07	4.0E-09
Thiourea	0.03	5.5E-04	1.8E-10
Toxaphene	3.0	3.2E-03	1.0E-07
Trichloroethane(1,1,2)	290	1.6E-05	5.0E-08
Trichloroethylene	1,900	1.7E-06	3.5E-08
Trichlorophenol(2,4,6)	0.71	5.7E-06	4.4E-11
Vinyl chloride	35	4.1E-06	1.6E-09
Total nationwide baseline emissions	93,000		1.2E-05

TSDF = Treatment, storage, and disposal facility.

[a]This table illustrates the calculation of the composite unit risk estimate for control option 1.

[b]Units are $(\mu g/m^3)^{-1}$.

TABLE E-4. CALCULATION OF THE EMISSIONS-WEIGHTED COMPOSITE UNIT RISK ESTIMATE (URE) FOR CONTROL OPTION 2[a]

Compound	Option 2 emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
Acetaldehyde	110	2.2E-06	2.5E-09
Acrylamide	6.0	1.1E-03	6.8E-08
Acrylonitrile	1,200	6.8E-05	8.7E-07
Aldrin	33	4.9E-03	1.7E-06
Aniline	37	7.4E-06	2.9E-09
Benzene	280	8.3E-06	2.4E-08
Benzo(a)pyrene	0.97	1.7E-03	1.7E-08
Benz(a)anthracene	0.20	8.9E-04	1.9E-09
bis(chloromethyl)ether	18	2.7E-03	4.9E-07
bis(2-chloroethyl)ether	0.14	3.3E-04	4.8E-10
Butadiene(1,3)	6.7	2.8E-04	1.9E-08
Carbon tetrachloride	1,200	1.5E-05	1.8E-07
Chlordane	5.4	3.7E-04	2.1E-08
Chloroform	160	2.3E-05	3.8E-08
Chloromethane	5.7	3.6E-06	2.1E-10
Chloromethyl(methyl)ether	0	2.7E-03	0.0E+00
DDT (4,4')	27	9.7E-05	2.7E-08
Dibenz(a,h)anthracene	0	1.4E-02	0.0E+00
Dibromo-(1,2)-chloropropane(3)	0.02	6.3E-03	1.3E-09
Dibromoethane	0	2.2E-04	0.0E+00
Dichloroethane(1,2)	920	2.6E-05	2.5E-07
Dichloroethylene(1,1)	87	5.0E-05	4.5E-08
Dinitrotoluene(2,4)	7.8	8.8E-05	7.1E-09
Dioxane(1,4)	12	1.4E-06	1.7E-10
Diphenylhydrazine(1,2)	0.11	2.2E-04	2.5E-10
Epichlorohydrin	79	1.2E-06	9.9E-10
Ethylene dibromide	0.55	2.2E-04	1.3E-09
Ethyleneoxide	0	1.0E-04	0.0E+00
Formaldehyde	230	1.3E-05	3.1E-08
Gasoline	146	6.6E-07	1.0E-09
Heptachlor	0.06	1.3E-03	8.1E-10
Hexachlorobenzene	4.9	4.9E-04	2.5E-08
Hexachlorobutadiene	3,600	2.2E-05	8.3E-07
Hexachloroethane	7.4	4.0E-06	3.1E-10
Hydrazine	20	2.9E-03	5.9E-07
Lindane	0	3.8E-04	0.0E+00
Methyl hydrazine	0.30	3.1E-04	9.7E-10
Methylcholanthrene(3)	4.7	2.7E-03	1.3E-07
Methylene chloride	610	4.7E-07	3.0E-09
Nitropropane(2)	0.27	2.7E-03	7.6E-09

(continued)

TABLE E-4 (continued)

Compound	Option 2 emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
N-Nitrosopyrrolidine	0	6.1E-04	0.0E+00
N-nitroso-n-methylurea	0	8.6E-02	0.0E+00
Polychlorinated biphenyls	0	1.2E-03	0.0E+00
Tetrachlorodibenzo(2,3,7,8)-p-dioxin	0.02	3.3E+01	6.9E-06
Tetrachloroethane(1,1,2,2)	26	5.8E-05	1.6E-08
Tetrachloroethylene	710	5.8E-07	4.3E-09
Thiourea	0.03	5.5E-04	1.7E-10
Toxaphene	3.8	3.2E-03	1.3E-07
Trichloroethane(1,1,2)	290	1.6E-05	4.8E-08
Trichloroethylene	2,300	1.7E-06	4.0E-08
Trichlorophenol(2,4,6)	0.74	5.7E-06	4.4E-11
Vinyl chloride	51	4.1E-06	2.2E-09
Total nationwide baseline emissions	96,000		1.3E-05

TSDF = Treatment, storage, and disposal facility.

[a]This table illustrates the calculation of the composite unit risk estimate for control option 2.

[b]Units are $(\mu g/m^3)^{-1}$.

TABLE E-5. CALCULATION OF THE EMISSIONS-WEIGHTED COMPOSITE UNIT RISK ESTIMATE (URE) FOR CONTROL OPTION 3[a]

Compound	Option 3 emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
Acetaldehyde	290	2.2E-06	4.8E-09
Acrylamide	8.1	1.1E-03	6.7E-08
Acrylonitrile	2,500	6.8E-05	1.3E-06
Aldrin	33	4.9E-03	1.2E-08
Aniline	39	7.4E-06	2.2E-09
Benzene	350	8.3E-06	2.2E-08
Benzo(a)pyrene	0.97	1.7E-03	1.2E-08
Benz(a)anthracene	0.20	8.9E-04	1.3E-09
bis(chloromethyl)ether	45	2.7E-03	9.1E-07
bis(2-chloroethyl)ether	0.27	3.3E-04	6.7E-10
Butadiene(1,3)	9.0	2.8E-04	1.9E-08
Carbon tetrachloride	1,200	1.5E-05	1.4E-07
Chlordane	5.4	3.7E-04	1.5E-08
Chloroform	490	2.3E-05	8.5E-08
Chloromethane	7.2	3.6E-06	1.9E-10
Chloromethyl(methyl)ether	0	2.7E-03	0.0E+00
DDT (4,4')	27	9.7E-05	2.0E-08
Dibenz(a,h)anthracene	0.01	1.4E-02	1.1E-09
Dibromo-(1,2)-chloropropane(3)	0.03	6.3E-03	1.4E-09
Dibromoethane	0	2.2E-04	0.0E+00
Dichloroethane(1,2)	1,400	2.6E-05	2.8E-07
Dichloroethylene(1,1)	89	5.0E-05	3.3E-08
Dinitrotoluene(2,4)	19	8.8E-05	1.3E-08
Dioxane(1,4)	21	1.4E-06	2.2E-10
Diphenylhydrazine(1,2)	0.17	2.2E-04	2.8E-10
Epichlorohydrin	200	1.2E-06	1.8E-09
Ethylene dibromide	6.2	2.2E-04	1.0E-08
Ethyleneoxide	0	1.0E-04	0.0E+00
Formaldehyde	360	1.3E-05	3.5E-08
Gasoline	280	6.6E-07	1.4E-09
Heptachlor	0.06	1.3E-03	5.9E-10
Hexachlorobenzene	5.2	4.9E-04	1.9E-08
Hexachlorobutadiene	3,600	2.2E-05	6.0E-07
Hexachloroethane	8.8	4.0E-06	2.6E-10
Hydrazine	25	2.9E-03	5.4E-07
Lindane	0	3.8E-04	0.0E+00
Methyl hydrazine	0.30	3.1E-04	7.0E-10
Methylcholanthrene(3)	4.7	2.7E-03	9.6E-08
Methylene chloride	810	4.7E-07	2.9E-09
Nitropropane(2)	0.61	2.7E-03	1.2E-08

(continued)

TABLE E-5 (continued)

Compound	Option 3 emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
N-Nitrosopyrrolidine	0	6.1E-04	0.0E+00
N-nitroso-n-methylurea	0	8.6E-02	0.0E+00
Polychlorinated biphenyls	0.01	1.2E-03	9.0E-11
Tetrachlorodibenzo(2,3,7,8)-p-dioxin	0.02	3.3E+01	5.0E-06
Tetrachloroethane(1,1,2,2)	40	5.8E-05	1.8E-08
Tetrachloroethylene	1,400	5.8E-07	6.0E-09
Thiourea	0.06	5.5E-04	2.5E-10
Toxaphene	4.2	3.2E-03	1.0E-07
Trichloroethane(1,1,2)	420	1.6E-05	5.1E-08
Trichloroethylene	4,400	1.7E-06	5.6E-08
Trichlorophenol(2,4,6)	1.1	5.7E-06	4.6E-11
Vinyl chloride	56	4.1E-06	1.7E-09
Total nationwide baseline emissions	133,000		1.06E-05

TSDF = Treatment, storage, and disposal facility.

[a]This table illustrates the calculation of the composite unit risk estimate for control option 3.

[b]Units are $(\mu g/m^3)^{-1}$.

TABLE E-6. CALCULATION OF THE EMISSIONS-WEIGHTED COMPOSITE UNIT RISK ESTIMATE (URE) FOR CONTROL OPTION 4[a]

Compound	Option 4 emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
Acetaldehyde	110	2.2E-06	1.7E-09
Acrylamide	6.0	1.1E-03	4.6E-08
Acrylonitrile	12,000	6.8E-05	5.6E-06
Aldrin	33	4.9E-03	1.1E-06
Aniline	37	7.4E-06	1.9E-09
Benzene	280	8.3E-06	1.7E-08
Benzo(a)pyrene	1.0	1.7E-03	1.2E-08
Benz(a)anthracene	0.20	8.9E-04	1.3E-09
bis(chloromethyl)ether	18	2.7E-03	3.3E-07
bis(2-chloroethyl)ether	0.10	3.3E-04	2.3E-10
Butadiene(1,3)	6.7	2.8E-04	1.3E-08
Carbon tetrachloride	1,200	1.5E-05	1.2E-07
Chlordane	5.4	3.7E-04	1.4E-08
Chloroform	160	2.3E-05	2.6E-08
Chloromethane	5.7	3.6E-06	1.4E-10
Chloromethyl(methyl)ether	0	2.7E-03	0.0E+00
DDT (4,4')	27	9.7E-05	1.8E-08
Dibenz(a,h)anthracene	0	1.4E-02	0.0E+00
Dibromo-(1,2)-chloropropane(3)	0	6.3E-03	0.0E+00
Dibromoethane	0	2.2E-04	0.0E+00
Dichloroethane(1,2)	920	2.6E-05	1.7E-07
Dichloroethylene(1,1)	98	5.0E-05	3.4E-08
Dinitrotoluene(2,4)	7.8	8.8E-05	4.8E-09
Dioxane(1,4)	130	1.4E-06	1.3E-09
Diphenylhydrazine(1,2)	0.70	2.2E-04	1.1E-09
Epichlorohydrin	79	1.2E-06	6.7E-10
Ethylene dibromide	0.50	2.2E-04	7.7E-10
Ethyleneoxide	0	1.0E-04	0.0E+00
Formaldehyde	230	1.3E-05	2.1E-08
Gasoline	150	6.6E-07	6.8E-10
Heptachlor	0.10	1.3E-03	9.2E-10
Hexachlorobenzene	4.9	4.9E-04	1.7E-08
Hexachlorobutadiene	3,600	2.2E-05	5.6E-07
Hexachloroethane	7.4	4.0E-06	2.1E-10
Hydrazine	20	2.9E-03	4.0E-07
Lindane	0	3.8E-04	0.0E+00
Methyl hydrazine	0.30	3.1E-04	6.5E-10
Methylcholanthrene(3)	4.7	2.7E-03	8.9E-08
Methylene chloride	610	4.7E-07	2.0E-09
Nitropropane(2)	0.30	2.7E-03	5.1E-09

(continued)

TABLE E-6 (continued)

Compound	Option 4 emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
N-Nitrosopyrrolidine	0	6.1E-04	0.0E+00
N-nitroso-n-methylurea	0	8.6E-02	0.0E+00
Polychlorinated biphenyls	0	1.2E-03	0.0E+00
Tetrachlorodibenzo(2,3,7,8)-p-dioxin	0.02	3.3E+01	4.6E-06
Tetrachloroethane(1,1,2,2)	26	5.8E-05	1.1E-08
Tetrachloroethylene	2,800	5.8E-07	1.1E-08
Thiourea	0.03	5.5E-04	1.2E-10
Toxaphene	3.8	3.2E-03	8.5E-08
Trichloroethane(1,1,2)	290	1.6E-05	3.2E-08
Trichloroethylene	2,800	1.7E-06	3.4E-08
Trichlorophenol(2,4,6)	0.70	5.7E-06	3.0E-11
Vinyl chloride	52	4.1E-06	1.5E-09
Total nationwide baseline emissions	142,000		1.4E-05

TSDF = Treatment, storage, and disposal facility.

[a]This table illustrates the calculation of the composite unit risk estimate for control option 4.

[b]Units are $(\mu g/m^3)^{-1}$.

TABLE E-7. CALCULATION OF THE EMISSIONS-WEIGHTED COMPOSITE UNIT RISK ESTIMATE (URE) FOR CONTROL OPTION 5[a]

Compound	Option 5 emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
Acetaldehyde	110	2.2E-06	1.4E-09
Acrylamide	6.0	1.1E-03	3.8E-08
Acrylonitrile	12,000	6.8E-05	4.6E-06
Aldrin	33	4.9E-03	9.3E-07
Aniline	52	7.4E-06	2.2E-09
Benzene	280	8.3E-06	1.3E-08
Benzo(a)pyrene	1.0	1.7E-03	9.7E-09
Benz(a)anthracene	0.20	8.9E-04	1.0E-09
bis(chloromethyl)ether	18	2.7E-03	2.7E-07
bis(2-chloroethyl)ether	1.8	3.3E-04	3.4E-09
Butadiene(1,3)	6.7	2.8E-04	1.1E-08
Carbon tetrachloride	1,200	1.5E-05	9.9E-08
Chlordane	5.4	3.7E-04	1.1E-08
Chloroform	160	2.3E-05	2.1E-08
Chloromethane	18	3.6E-06	3.7E-10
Chloromethyl(methyl)ether	0	2.7E-03	0.0E+00
DDT (4,4')	27	9.7E-05	1.5E-08
Dibenz(a,h)anthracene	0	1.4E-02	0.0E+00
Dibromo-(1,2)-chloropropane(3)	0.10	6.3E-03	3.6E-09
Dibromoethane	0	2.2E-04	0.0E+00
Dichloroethane(1,2)	1,800	2.6E-05	2.7E-07
Dichloroethylene(1,1)	100	5.0E-05	2.9E-08
Dinitrotoluene(2,4)	7.8	8.8E-05	3.9E-09
Dioxane(1,4)	130	1.4E-06	1.1E-09
Diphenylhydrazine(1,2)	0.70	2.2E-04	8.8E-10
Epichlorohydrin	79	1.2E-06	5.4E-10
Ethylene dibromide	0.50	2.2E-04	6.3E-10
Ethyleneoxide	0	1.0E-04	0.0E+00
Formaldehyde	390	1.3E-05	2.9E-08
Gasoline	150	6.6E-07	5.5E-10
Heptachlor	0.10	1.3E-03	7.4E-10
Hexachlorobenzene	8.0	4.9E-04	2.2E-08
Hexachlorobutadiene	3,600	2.2E-05	4.6E-07
Hexachloroethane	7.4	4.0E-06	1.7E-10
Hydrazine	41	2.9E-03	6.9E-07
Lindane	0	3.8E-04	0.0E+00
Methyl hydrazine	0.30	3.1E-04	5.3E-10
Methylcholanthrene(3)	4.7	2.7E-03	7.3E-08
Methylene chloride	620	4.7E-07	1.7E-09
Nitropropane(2)	0.30	2.7E-03	4.2E-09

(continued)

TABLE E-7 (continued)

Compound	Option 5 emissions, Mg/yr	URE[b]	URE x emissions for chemical[b] / Total TSDF emissions
N-Nitrosopyrrolidine	0	6.1E-04	0.0E+00
N-nitroso-n-methylurea	0	8.6E-02	0.0E+00
Polychlorinated biphenyls	0	1.2E-03	0.0E+00
Tetrachlorodibenzo(2,3,7,8)-p-dioxin	0.02	3.3E+01	3.8E-06
Tetrachloroethane(1,1,2,2)	29	5.8E-05	9.7E-09
Tetrachloroethylene	2,800	5.8E-07	9.2E-09
Thiourea	0.03	5.5E-04	9.4E-11
Toxaphene	3.9	3.2E-03	7.1E-08
Trichloroethane(1,1,2)	290	1.6E-05	2.7E-08
Trichloroethylene	2,900	1.7E-06	2.8E-08
Trichlorophenol(2,4,6)	12	5.7E-06	3.8E-10
Vinyl chloride	52	4.1E-06	1.2E-09
Total nationwide baseline emissions	175,000		1.2E-05

TSDF = Treatment, storage, and disposal facility.

[a]This table illustrates the calculation of the composite unit risk estimate for control option 5.

[b]Units are $(\mu g/m^3)^{-1}$.

to gross effects such as death. The effects of greatest concern are the ones that are irreversible and impair the normal functioning of the individual. Some of these effects include respiratory toxicity, developmental and reproductive toxicity, central nervous system effects, and other systemic effects such as liver and kidney toxicity, cardiovascular toxicity, and immunotoxicity.

E.2.1 Health Benchmark Levels

For chemicals that give rise to toxic endpoints other than cancer and gene mutations, there appears to be a level of exposure below which adverse health effects usually do not occur. This threshold-of-effect concept maintains that an organism can tolerate a range of exposures from zero to some finite value without risk of experiencing a toxic effect. Above this threshold, toxicity is observed as the organism's homeostatic, compensating, and adaptive mechanisms are overcome. To provide protection against adverse health effects in even the most sensitive individuals in a population, regulatory efforts are generally made to prevent exposures from exceeding a health "benchmark" level that is below the lowest of the thresholds of the individuals within a population.

Benchmark levels, termed reference doses (RfDs), are operationally derived from an experimentally obtained no-observed-effect level or a lowest-observed-effect level by consistent application of generally order-of-magnitude uncertainty factors that reflect various types of data used to estimate the RfD. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effect.

The Agency has developed verified oral RfD for a large number of chemicals, but has only recently established an internal work group to begin the process for establishing inhalation RfDs. Agency-verified inhalation reference doses for acute and chronic exposures will be used in this analysis when they become available. Unverified inhalation reference doses that have been developed by the Agency may be used on an interim basis after careful review of the supporting data base.

E.2.2 Noncarcinogenic Chemicals of Concern

A preliminary list of 179 TSDF chemicals of concern for the noncancer health assessment is shown in Table E-8. Constituents were drawn from the Agency's final rule on the identification and listing of hazardous waste (Appendix VIII)[14] and from the Industry Studies Data Base, a hazardous waste data base developed by EPA's Office of Solid Waste.[15] To be selected from these sources, the chemical must have had either an Agency-verified oral reference dose (as of September 30, 1987),[16] or a Reference Air Concentration (RAC) found in the Agency's proposed rule on the burning of hazardous waste in boilers and industrial furnaces.[17] Additional chemicals were added to Table E-8 based on knowledge of a high toxicity associated with that substance.

E.3 EXPOSURE ASSESSMENT

Three models were used to assess exposure, and ultimately risks, for air emissions from TSDF. The Human Exposure Model (HEM) was used to calculate the number of people exposed to predicted ambient concentrations of total volatile organics (VO) at each of about 2,300 TSDF in the United States. The results of these analyses were used to quantify annual cancer incidence. To determine the maximum lifetime cancer risk, the Industrial Source Complex Long-Term (ISCLT) model was used to estimate the highest ambient concentrations of VO in the vicinity of two TSDF. In addition, this model was used in the evaluation of chronic noncancer health effects. Finally, the Industrial Source Complex Short-Term (ISCST) model was used to estimate ambient concentrations of individual chemicals of concern for the acute noncancer health effects assessment and as a preliminary screen for the chronic noncancer health effects assessment. Each of these is briefly described below.

E.3.1 Human Exposure Model

In addition to the composite unit risk estimate, a numerical expression of public exposure to the pollutant is needed to produce quantitative expressions of cancer incidence. The numerical expression of public exposure is based on two estimates: (1) an estimate of the magnitude and location of long-term average air concentrations of the pollutant in the vicinity of emitting sources based on air dispersion modeling; and (2) an

TABLE E-8. TSDF CHEMICALS - NONCANCER HEALTH EFFECTS ASSESSMENT

Chemical	Chemical
acetone (67-64-1)	bromoform (75-25-2)
acetaldehyde[a] (75-07-0)	butanol (71-36-3)
acetonitrile (75-05-8)	cadmium[a] (7440-43-9)
acetophenone (98-86-2)	calcium chromate[a] (13765-19-0)
acetyl chloride (75-36-5)	calcium cyanide (592-01-8)
1-acetyl-2-thiourea (591-08-2)	carbon disulfide (75-15-0)
acrolein[a] (107-02-8)	carbon oxyfluoride (353-50-4)
acrylic acid (79-10-7)	carbon tetrachloride[a] (56-23-5)
acrylonitrile[a] (107-13-1)	chlordane[a] (12789-03-6)
aldicarb (116-06-3)	chlorine (7782-50-5)
aldrin[a] (309-00-2)	chloroacetaldehyde (107-20-0)
allyl alcohol (107-18-6)	2-chloro-1,3-butadiene
allyl chloride[a] (107-05-1)	(126-99-8)
aluminum phosphide (20859-73-8)	chloroform[a] (67-66-3)
5-aminomethyl-3-isoxazolol	chloromethane[a] (74-87-3)
(2763-96-4)	3-chloropropionitrile (542-76-7)
4-aminopyridine (504-24-5)	chromium III (7440-47-3)
ammonia (7664-41-7)	chromium VI (7440-47-3)
ammonium vanadate (7803-55-6)	copper cyanide (544-92-3)
antimony (7440-36-0)	cresols[a] (1319-77-3)
arsenic[a] (7440-38-2)	crotonaldehyde (4170-30-3)
barium (7440-39-3)	cumene (98-82-8)
barium cyanide (542-62-1)	cyanide (57-12-5)
benzidine[a] (92-87-5)	cyanogen (460-19-5)
benzoic acid (65-85-0)	cyanogen bromide[a] (506-68-3)
beryllium[a] (7440-41-7)	cyanogen chloride (506-77-4)
1,1-biphenyl (92-52-4)	cyclohexanone (108-94-1)
bis(2-ethylhexyl)phthalate[a]	2,4 D (dichlorophenoxyacetic
(117-81-7)	acid) (94-75-7)
bromodichloromethane (75-27-4)	DDT[a] (50-29-3)

(continued)

TABLE E-8 (continued)

Chemical	Chemical
decabromodiphenyl oxide (1163-19-5)	ethylene thiourea[a] (96-45-7)
di-n-butyl phthalate (84-74-2)	fluoracetic acid, sodium salt (62-74-8)
1,2-dichlorobenzene (95-50-1)	fluoride (16984-48-8)
1,4-dichlorobenzene[a] (106-46-7)	fluorine (7782-41-4)
dichlorodifluoromethane (75-71-8)	formaldehyde[a] (50-00-0)
1,1-dichloroethane[a] (75-34-3)	formic acid (64-18-6)
1,1-dichloroethylene[a] (75-35-4)	freon 113 (76-13-1)
2,4-dichlorophenol (120-83-2)	furan (110-00-9)
1,3-dichloropropene[a] (542-75-6)	gamma-hexachlorocyclohexane (lindane) (58-89-9)
dieldrin[a] (60-57-1)	heptachlor[a] (76-44-8)
diethyl phthalate (84-66-2)	heptachlor epoxide[a] (1024-57-3)
dimethoate (60-51-5)	hexachlorobutadiene[a] (87-68-3)
dimethyl amine (124-40-3)	hexachlorocyclopentadiene (77-47-4)
dimethyl aniline (121-69-7)	hexachloroethane[a] (67-72-1)
(alpha, alpha) dimethyl phenethylamine (122-09-8)	hydrogen chloride (7647-01-0)
dimethylterephthalate (120-61-6)	hydrogen cyanide (74-90-8)
2,4-dinitrophenol (51-28-5)	hydrogen sulfide (7783-06-4)
dinoseb (88-85-7)	isobutyl alcohol (78-83-1)
diphenyl amine (122-39-4)	lead (7439-92-1)
disulfoton (298-04-4)	maleic hydrazide[a] (123-33-1)
endosulfan (115-29-7)	malononitrile (109-77-3)
endothall (129-67-9)	mercury (7439-97-6)
endrin (72-20-8)	methacrylonitrile (126-98-7)
epichlorohydrin[a] (chloro-2,3-epoxy-propane) (106-89-8)	methomyl (16752-77-5)
ethyl acetate (141-78-6)	methoxyclor (72-43-5)
ethyl benzene (100-41-4)	methyl bromide (bromomethane) (74-83-9)
ethylene glycol (107-21-1)	
ethylene oxide[a] (75-21-8)	

(continued)

TABLE E-8 (continued)

Chemical	Chemical
methyl chloroform (1,1,1-trichloroethane) (71-55-6)	selenious acid (selenium dioxide) (7783-00-8)
methylene chloride[a] (75-09-2)	selenourea (630-10-4)
methyl ethyl ketone (78-93-3)	silver (7440-22-4)
methyl iodide[a] (74-88-4)	silver cyanide (506-64-9)
methyl isobutyl ketone (108-10-1)	silvex (93-72-1)
methyl isocyanate (624-83-9)	sodium azide (26628-22-8)
2-methyl lactonitrile (75-86-5)	sodium cyanide (143-33-9)
methyl parathion (298-00-0)	styrene[a] (100-42-5)
nickel carbonyl[a] (13463-39-3)	strychnine (57-24-9)
nickel cyanide (557-19-7)	1,2,4,5-tetrachlorobenzene (95-94-3)
nickel refinery dust[a] (7440-02-2)	1,1,1,2-tetrachloroethane[a] (630-20-6)
nitric oxide (10102-43-9)	tetrachloroethylene[a] (127-18-4)
nitrobenzene[a] (98-95-3)	2,3,4,6-tetrachlorophenol (58-90-2)
4-nitroquinoline-1-oxide (56-57-5)	tetraethyl dithiopyrophosphate (3689-24-5)
osmium tetroxide (20816-12-0)	tetraethyl lead (78-00-2)
pentachlorobenzene[a] (608-93-5)	thallic oxide (1314-32-5)
pentachloroethane[a] (76-01-7)	thallium (7440-28-0)
pentachloronitrobenzene (82-68-8)	thallium (1) acetate (563-68-8)
pentachlorophenol[a] (87-86-5)	thallium (1) carbonate (6533-73-9)
phenol (108-95-2)	thallium (1) chloride (7791-12-0)
m-phenylenediamine[a] (25265-76-3)	thallium (1) nitrate (10102-45-1)
phenylmercuric acetate (62-38-4)	thallium (1) selenite (12039-52-0)
phosgene (75-44-5)	thallium (1) sulfate (10031-59-1)
phosphine (7803-51-2)	thiomethanol (methyl mercaptan) (74-93-1)
potassium cyanide (151-50-8)	thiosemicarbazide (79-19-6)
potassium silver cyanide (506-61-6)	
pronamide[a] (23950-58-5)	
propanenitrile (107-12-0)	
n-propylamine (107-10-8)	
2-propyn-1-ol (107-19-7)	
pyridine (110-86-1)	

(continued)

TABLE E-8 (continued)

Chemical	Chemical
thiram (137-26-8)	1,2,3-trichloropropane (96-18-4)
toluene (108-88-3)	vanadium pentoxide (1314-62-1)
1,2,4-trichlorobenzene (120-82-1)	warfarin (81-81-2)
1,1,2-trichloroethane[a] (79-00-5)	xylene(s) (1330-20-7)
trichloromonofluoromethane (75-69-4)	zinc cyanide (557-21-1)
	zinc phosphide (12037-79-5)
2,4,5-trichlorophenol[a] (95-95-4)	zineb[a] (12122-67-7)

( ) = Chemical Abstracts Service (CAS) Number.

[a]Carcinogen.

estimate of the number of people living in the vicinity of emitting sources.

The EPA uses the Human Exposure Model (HEM) to make these quantitative estimates of public exposure and risk associated with a pollutant. The HEM uses an atmospheric dispersion model that includes meteorological data and a population distribution estimate based on 1980 Bureau of Census data to calculate public exposure.[18]

The dispersion model in HEM used data for a model plant that was placed at each TSDF location (initially about 5,000 sites). The location of each TSDF was obtained from the TSDF Industry Profile (see Appendix D, Section D.2.1). Inputs to the initial run included a unit cancer potency estimate (1.0) and a unit emission rate (10,000 kg VOC/yr). In addition, an exit velocity and an effluent outgas temperature of 0.1 m/s and 293 K were assumed. These inputs were used to estimate the concentration and distribution of the pollutant at distances of 200 m to 50 km from the source. The population distribution estimates for people residing near the source are based on Bureau of Census data contained in the 1980 Master Area Reference File (MARF) data base.[19] The data base is broken down into enumeration district/block group (ED/BG) values. The MARF contains the population centroid coordinates (latitude and longitude) and the 1980 population of each ED/BG (approximately 300,000) in the United States. By knowing the geographic location of the plant (latitude and longitude), the model can identify the ED/BG that fall within the 50-km radius used by HEM.

The HEM multiplies the concentration of the pollutant at ground level at each of the 160 receptors around the plant by the number of people exposed to that concentration to produce the exposure estimates. The total exposure, as calculated by HEM, is illustrated by the following equation:

$$\text{Total exposure} = \sum_{i=1}^{N} (P_i)(C_i) \quad , \qquad \text{(E-2)}$$

Σ = summation over all grid points where exposure is calculated

P_i = population associated with grid point i

C_i = long-term average pollutant concentration at grid point i

N = number of grid points.

The HEM assumes that: (1) people stay at the same location (residence) and are exposed to the same concentrations of the pollutant for 70 years; (2) the terrain around the plant is flat; and (3) concentrations of the pollutant are the same inside and outside the residence.

E.3.2 ISCLT Model

As noted above, the ISCLT model was used to estimate ambient concentrations of VO for estimating maximum lifetime risk for the cancer health effects assessment and the chronic noncancer effects study. The ISCLT model is a steady-state, Gaussian plume, atmospheric dispersion model that is applicable to multiple point, area, and volume emission sources. It is designed specifically to estimate long-term ambient concentrations of pollutants in the vicinity of industrial source complexes. The model was applied to two TSDF to estimate the highest concentrations of VO and individual chemicals at the fenceline, or beyond, of two TSDF. As described later in Section E.4, the highest ambient VO concentrations are used with the composite unit risk estimate to calculate maximum lifetime risk. A detailed discussion of the model and its application to the two TSDF is contained in Appendix J.

E.3.3 ISCST Model

The ISCST model was used to estimate ambient concentrations of individual hazardous waste constituents for purposes of evaluating acute, noncancer health risks. It was also used as a screening tool to identify which of the chemicals of concern in Table E-8 should be further evaluated with the ISCLT (see also Appendix J). The ISCST is similar in nature to the ISCLT, except that it is suitable for estimating short-term ambient concentrations (e.g., concentrations averaged over 1 h, 3 h, 8 h, 24 h, etc.) as well as long-term averages. ISCST was applied to two TSDF to estimate the highest constituent concentrations for variable averaging times at the fencline or beyond. A detailed description of this model and its application are also contained in Appendix J.

E.4 RISK ASSESSMENT

E.4.1 Cancer Risk Measurements

Three pieces of information are needed to assess the cancer risks of exposure to TSDF air emissions: (1) an estimate of the carcinogenic potency, or unit risk estimate, of the pollutants in TSDF air emissions; (2) an estimate of the ambient concentration of the pollutants from a TSDF that an individual or group of people breathe; and (3) an estimate of the number of people who are exposed to those concentrations.

Multiplying the composite unit risk estimate by (1) the numerical expressions of public exposure obtained from HEM and (2) the maximum concentration predicted by ISCLT gives two types of cancer risk measures: (1) annual incidence, a measure of population or aggregate risk, and (2) individual risk or maximum lifetime risk. The definition and calculation of annual incidence are discussed in the next section. Maximum lifetime risks are discussed in Section E.4.1.2.

E.4.1.1 Annual Cancer Incidence. One expression of risk is annual cancer incidence, a measure of aggregate risk. Aggregate risk is the summation of all the risks to people estimated to be living within the vicinity (usually within 50 km) of a source. It is calculated by multiplying the estimated concentrations of the pollutants by the unit risk estimate by the number of people exposed to different concentrations. This estimate reflects the number of excess cancers among the total population after 70 years of exposure. For statistical convenience, the aggregate risk is divided by 70 and expressed as cancer incidence per year.[20]

A unit cancer potency estimate of 1.0 and a unit emission rate of 10,000 g/yr were used as input data for HEM. Annual incidence attributed to each TSDF, as calculated by using HEM, is proportional to the cancer potency estimate and emissions. Thus, another model was used to scale the annual incidence for each TSDF by the estimated composite unit risk estimate and by the estimated VO emission that were attributed to each TSDF:

$$\text{Annual incidence} = \text{HEM annual incidence} \times \frac{\text{Composite unit risk estimate}}{1.0} \times \frac{\text{VO emissions for TSDF XX}}{10{,}000\ \text{kg}} \quad \text{(E-3)}$$

The annual incidences were then summed over all TSDF. This scaling and final aggregation was performed with the Source Assessment Model (SAM) (see Appendix D).

E.4.1.2 Maximum Lifetime Risk. Maximum lifetime risk or individual risk refers to the person or persons estimated to live in the area of highest ambient air concentrations of the pollutant(s) as determined by the detailed facility modeling. The maximum lifetime risk reflects the probability of an individual developing cancer as a result of continuous exposure to the estimated maximum ambient air concentration for 70 years. The use of the word "maximum" in maximum lifetime risk does not mean the greatest possible risk of cancer to the public. It is based only on the maximum exposure estimated by the procedure used,[21] and it does not incorporate uncertainties in the exposure estimate or the unit risk estimate.

Maximum lifetime risk is calculated by multiplying the highest ambient air concentration by the composite unit risk estimate. The product is the probability of developing cancer for those individuals assumed to be exposed to the highest concentration for their lifetimes. Thus,

$$\text{Maximum lifetime risk} = \begin{pmatrix}\text{Composite unit risk} \\ \text{estimate at 1 } \mu g/m^3\end{pmatrix} \times \begin{pmatrix}\text{Highest} \\ \text{ambient air} \\ \text{concentration}\end{pmatrix} . \qquad \text{(E-4)}$$

E.4.2 Noncancer Health Effects

E.4.2.1 Chronic Exposures. The assessment of noncancer health effects associated with chronic exposures to TSDF chemicals of concern is based on a comparison of the chemical-specific health benchmark levels (as discussed in Section E.2.1) to estimated ambient concentrations at various receptor locations around a facility. Inhalation exposure limits are compared to the highest annual average ambient concentration for each chemical at the selected facilities. These annual concentrations represent an estimation of the highest average daily ambient concentration experienced over a year. Ambient concentrations that are less than the RfD are not likely to be associated with health risks. The probability that adverse effects may be observed in a human population increases as the frequency of exposures exceeding the RfD increases and as the size of the excess increases.

Because Agency-verified RfD were not available, an interim screening approach was used. The likelihood of adverse noncancer health effects was determined by comparing modeled ambient concentrations of individual constituents to the available health data. These health data were obtained from various sources, including EPA reports and documents, data used to support occupational exposure recommendations and standards (e.g., American Conference of Governmental Industrial Hygienists, Documentation of the Threshold Limit Values), and other published information. An assessment of the potential for adverse noncancer health effects was made case-by-case, considering: (1) the magnitude of the differences between the exposure concentration and the lowest-observed-adverse-effect level or the no-observed-adverse-effect level, and (2) the quality of the health effects data base. The modeled ambient concentrations in Appendix J, Tables J-18 and J-19, were compared to the information in health effects documentation for noncancer chemicals.[22] the modeled concentrations were, in most cases, three orders of magnitude below health effects levels of concern. The probability that such effects will occur increases with increasing exposure concentrations. This screening effort was used only to give a preliminary indication of the potential for noncancer health effects, and will be replaced by an analysis that uses inhalation reference doses as they become available.

E.4.2.2 Acute Exposures. An assessment of the potential for noncancer health effects associated with short-term (acute) exposure to TSDF chemicals of concern at selected facilities was conducted as a screening effort to provide additional qualitative support to the overall noncancer health effects analysis. In addition to the lack of short-term inhalation health benchmark levels at this time, acute inhalation data are limited for many of the TSDF chemicals of concern. The assessment was conducted by comparing maximum modeled ambient concentrations for averaging times of 15 min, 1 h, 8 h, and 24 h to available short-term health data matched to the appropriate averaging time. A determination of the risk of adverse health effects associated with estimated short-term exposures was based on a consideration of the quality of the available health data and the proximity of the exposure concentration to the health effect level. The modeled

ambient concentrations in Appendix J, Tables J-18 and J-19, were compared to the information in health effects documentation for noncancer chemicals.[23] The modeled concentrations were, in most cases, three orders of magnitude below health effects levels of concern.

E.5 ANALYTICAL UNCERTAINTIES APPLICABLE TO CALCULATIONS OF PUBLIC HEALTH RISKS IN THIS APPENDIX

E.5.1 Unit Risk Estimate

The procedure generally used to develop unit risk estimates is fully described in Reference 1, using nickel as an example. The low-dose extrapolation model used and its application to epidemiological and animal data have been the subjects of substantial comment by health scientists. The uncertainties are too complex to be summarized in this appendix. Readers who wish to go beyond the information presented in the reference should see the following Federal Register notices: (1) EPA's "Guidelines for Carcinogenic Risk Assessment," 51 FR 33972 (September 24, 1986), and (2) EPA's "Chemical Carcinogens; A Review of the Science and Its Associated Principles," 50 FR 10372 (March 14, 1985), February 1985.

Significant uncertainties associated with the cancer unit risk estimates include: (1) selection of dose-response model, (2) selection of study used to estimate the unit risk estimate, and (3) presence or absence of a threshold. Uncertainties related to the composite risk estimate include the assumption of additivity of carcinogenic risk. According to the EPA "Guidelines for the Health Risk Assessment of Mixtures," a number of factors such as data on similar mixtures and the interactions among chemicals must be considered before additivity can be assumed.[24] Because of the sheer number of chemicals emitted from TSDF and the lack of specific information on particular compounds, EPA assumed additivity.

E.5.2 Public Exposure

E.5.2.1 General. The basic assumptions implicit in the methodology are that all exposure occurs at people's residences, that people stay at the same location for 70 years, that the ambient air concentrations and the emissions that cause these concentrations persist for 70 years, and that the concentrations are the same inside and outside the residences. From

this it can be seen that public exposure is based on a hypothetical rather than a realistic premise. It is not known whether this results in an overestimation or an underestimation of public exposure.

E.5.2.2 The Public. The following are relevant to the public as dealt with in this analysis:

- Studies show that all people are not equally susceptible to cancer. There is no numerical recognition of the "most susceptible" subset of the population exposed.

- Studies indicate that whether or not exposure to a particular carcinogen results in cancer may be affected by the person's exposure to other substances. The public's exposure to other substances is not numerically considered.

- Some members of the public included in this analysis are likely to be exposed to compounds in the air in the workplace, and workplace air concentrations of a pollutant are customarily much higher than the concentrations found in the ambient or public air. Workplace exposures are not numerically approximated.

- Studies show that there is normally a long latency period between exposure and the onset of cancer. This has not been numerically recognized.

- The people dealt with in the analysis are not located by actual residences. As explained previously, they are "located" in the Bureau of Census data for 1980 by population centroids of census districts.

- Many people dealt with in this analysis are subject to exposure to ambient air concentrations of potentially toxic pollutants where they travel and shop (as in downtown areas and suburban shopping centers), where they congregate (as in public parks, sports stadiums, and school yards), and where they work outside (as mailmen, milkmen, and construction workers). These types of exposures are not dealt with numerically.

E.5.2.3 Ambient Air Concentrations. The following are relevant to the estimated ambient air concentrations used in this analysis:

- Flat terrain was assumed in the dispersion model. Concentrations much higher than those estimated would result if emissions impact on elevated terrain or tall building near a plant.

- The estimated concentrations do not account for the additive impact of emissions from plants located close to one another.

- Meteorological data specific to plant sites are not used in the dispersion model. As explained, meteorological data from a National Weather Service station nearest the plant site are used. Site-specific meteorological data could result in significantly different estimates, e.g., the estimates of where the higher concentrations occur.

- With few exceptions, the emission rates are based on assumptions and on limited emission tests. See the Background Information Document for details on each source.

E.6 REFERENCES

1. U.S. Environmental Protection Agency. Health Assessment Document for Nickel and Nickel Compounds. Publication No. EPA-600/8-83-012FF. Office of Health and Environmental Assessment, Washington, DC. 1986. p. 8-156.

2. Reference 1, p. 8-156.

3. U.S. Environmental Protection Agency. Carcinogen Assessment of Coke Oven Emissions. Publication No. EPA-600/6-82-003F. Office of Health and Environmental Assessment. Washington, DC. 1984. p. 147.

4. Reference 1, p. 8-161.

5. Reference 1, p. 8-179.

6. Reference 1, p. 8-162.

7. Reference 1, p. 8-179.

8. U.S. Environmental Protection Agency. Health Assessment Document for Carbon Tetrachloride. Publication No. EPA-600/8-82-001F. Environmental Criteria and Assessment Office, Cincinnati, OH. September 1984. p. 12-10.

9. U.S. Environmental Protection Agency. Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Final Rule. 51 FR 28296. August 6, 1986.

10. Memorandum from Lisa Ratcliff, EPA, to Bob Scarberry and Debra Dobkowski, EPA. June 29, 1987. Inhalation exposure limits.

11. Reference 10.

12. Memorandum from Branscome, M., RTI, to Docket. September 28, 1988. Calculation of composite unit risk estimates.

13. U.S. Environmental Protection Agency. Guidelines for Carcinogen Risk Assessment. 51 FR 33992. September 24, 1986.

14. Reference 9.

15. Memorandum from Coy, Dave, RTI, to McDonald, Randy, EPA/OAQPS. May 2, 1986. Listing of waste constituents prioritized by quantity.

16. U.S. Environmental Protection Agency. Status Report of the RfD Work Group. Environmental Criteria and Assessment office, Cincinnati, OH. 1987.

17. U.S. Environmental Protection Agency. Burning of Hazardous Waste in Boilers and Industrial Furnaces; Preamble Correction. 52 FR 25612. July 8, 1987.

18. U.S. Environmental Protection Agency. User's Manual for the Human Exposure Model (HEM). Office of Air Quality Planning and Standards, Research Triangle park, NC. Publication No. EPA/450/5-86-001. 1986.

19. Department of Commerce. Local Climatological Data. Annual Summaries with Comparative Data. 1967.

20. U.S. Environmental Protection Agency. Inorganic Arsenic NESHAPs: Response to Public Comments on Health, Risk Assessment, and Risk Management. Publication No. EPA/450-5-85-001. Office of Air Quality, Planning, and Standards, Research Triangle Park, NC. April 1985. p. 4-13.

21. Reference 20, p. 4-18.

22. Alliance Technologies Corporation. Estimation of Human Health Risks from Exposure to Air Emissions from Treatment, Storage, and Disposal Facilities. Prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC. July 22, 1988. 107 p.

23. Reference 22.

24. U.S. Environmental Protection Agency. Guidelines for the Health Risk Assessment of Chemical Mixtures. 51 FR 34014. September 24, 1986.

25. Chemical Manufacturers Association. Comments of the Chemical Manufacturers Association on the Environmental Protection Agency Document, "Hazardous Waste TSDF - Background Information for Proposed RCRA Air Emission Standards - Volumes I and II." Washington, D.C. July 11, 1988. 105 p.

APPENDIX F

TEST DATA

APPENDIX F

TEST DATA

An ongoing test program is being conducted to develop an air emission data base in support of standards to control emissions from hazardous waste treatment, storage, and disposal facilities (TSDF).

The purposes of the test program are to:

- Provide an indication of air emission levels from TSDF
- Evaluate effectiveness of emission controls
- Evaluate measurement techniques for determining air emissions from hazardous waste TSDF
- Evaluate modeling techniques for estimating air emissions from hazardous waste TSDF.

Source testing has been conducted at TSDF covering five categories:

- Surface impoundments
- Wastewater treatment (WWT) systems
- Active and inactive landfills
- Land treatment facilities
- Transfer, storage, and handling operations.

In addition, data are available from petroleum transfer, storage, and handling operations and from fugitive sources at petroleum refineries and synthetic organic chemical manufacturing industries (SOCMI) facilities that are applicable to TSDF fugitive emission sources.

The types of controls that have been tested are add-on controls for the suppression of emissions, capture and containment devices to control vented off-gases, and volatile organic (VO) removal processes such as steam

strippers and thin-film evaporators. These sources have been tested for their effectiveness as well as any emissions they produce.

The subsequent sections of this appendix summarize the available test data by TSDF emission source category and control type. For each source category, descriptions of the facility and types of wastes managed per facility are presented, along with air emission sources tested, objectives of tests, sampling locations, sampling and analytical techniques used, and tabular summaries of test results. (Note: The use of "VO" in the presentation of test results does not refer to test results from the VO test method described in Appendix G.)

Tables F-1 through F-9 present summaries of tests. There are two summary tables for surface impoundments, two for WWT systems, and two for landfills. The first of each pair of tables presents general information including test site identification number, test site location, test description, test year, test sponsor, and test duration. The second table of each pair presents measured emission data. Summaries of testing and test results for land treatment; transfer, storage, and handling operations; and controls are each presented in one table. Each table includes site identification number, test site location, test year, test sponsor, test description, test duration, test procedure, source tested or control tested, and summary of test results.

F.1 TEST DATA AT EMISSION SOURCES

F.1.1 Surface Impoundments

F.1.1.1 Site 1.[1] Site 1 is a RCRA-permitted commercial hazardous waste TSDF. The facility includes four general waste management processes: surface impoundments (ponds), landfills, wastewater treatment unit, and solvent recovery. Ponds 2, 6, and 8 are currently being used as surface impoundments. Pond 2 acts as the receiving basin. An oil film covers much of its surface, and floating solid debris is visible on the pond's surface as well. Pond 2 has a capacity of approximately 5,700 m^3. Each of the surface impoundments is operated with approximately 1.5 m of freeboard; the dimensions of each of the surface impoundments are given in Table F-10.

From Pond 2, the aqueous waste is pumped to Pond 6. Caustic is added to the wastewater at Pond 6 to raise the pH to approximately 11, and polymer is added to promote solids settling. Pond 6 has a capacity of about 9,500 m^3.

TABLE F-1. SUMMARY OF TSDF SURFACE IMPOUNDMENT TESTING[a]

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration
1	Oklahoma commercial TSDF	Field test (3 impoundments) • Liquid samples • Biological activity testing	1987	EPA/ORD	1 day
2	California commercial TSDF	Field test (4 impoundments) • Liquid samples • Biological activity testing	1986	EPA/ORD	1 day
3	Louisiana refinery/lubricating oil plant	Field test (1 impoundment) • Liquid samples • Biological activity testing	1986	EPA/ORD	1 day
4	Texas chemical manufacturing plant	Field test (1 impoundment) • Liquid samples • Biological activity testing	1986	EPA/ORD	1 day
5	Mississippi chemical manufacturing plant	Field test (1 impoundment) • Flux chamber • Liquid samples • Sludge samples	1985	EPA/OAQPS	3 days
6	California commercial TSDF	Field test (1 impoundment) • Flux chamber • Liquid samples	1984	EPA/OAQPS	2 days
7	New York commercial TSDF	Field test (3 impoundments) • Flux chamber • Liquid samples	1983	EPA/ORD	1 week

TSDF = Treatment, storage, and disposal facility.
ORD = Office of Research and Development.
OAQPS = Office of Air Quality Planning and Standards.

[a]This table presents a summary of the air emission, liquid concentration, and biological activity testing conducted at TSDF surface impoundments.

TABLE F-2. SUMMARY OF TSDF SURFACE IMPOUNDMENT MEASURED EMISSION RATES AND MASS TRANSFER COEFFICIENTS[a]

Test site	Area tested, m^2	Total NMHC, Mg/yr	Mass transfer coefficient, x 10^6 m/s						
			Toluene	Ethylbenzene	Methylene chloride	1,1,1-Trichloroethane	Chloroform	p-Dichlorobenzene	Benzene
Site 5									
Holding lagoon	3,780	15	9.0	NA	NA	NA	NA	NA	3.7
Site 6[b]									
Evaporation pond	6,300								
June 20, 1984[c]		16	0.2	0.2	0.7	1.2	0.9	0.3	NA
June 22, 1984		61	2.4	1.0	8.4	2.6	12	0.4	NA
Site 7									
Holding pond[d]	4,860	1.2	2.3	2.6	3.1	<0.039	2.2	4.3	2.7
Reducing lagoon[e]	1,120	0.6	5.0	5.5	12	7.6	5.7	2.6	4.9
Oxidizing lagoon[e]	1,230	7.6	0.38	0.037	NA	35	NA	NA	NA

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.
NA = Not available.

[a]This table presents a summary of the NMHC air emission rates measured using the flux chamber technique and calculated mass transfer coefficients for specific constituents from TSDF surface impoundment testing.

[b]During flux chamber measurements, an additional 30.5 m (100 ft) of sampling line was required to reach the sampling locations. Under normal conditions, 3.1 m (10 ft) of sampling line would be used.

[c]During collection of the canister samples on June 20 at two sampling points, the chamber differential pressure was higher than normal. This abnormality may have affected these canister results on June 20.

[d]Field test took place several days after draining; consequently, the pond had a nominal 0.3 to 0.5 m (1 to 1.5 ft) of liquid waste and several meters of sludge present.

[e]The surface of the lagoon was coated with an oil film.

TABLE F-3. SUMMARY OF TSDF WASTEWATER TREATMENT SYSTEM TESTING[a]

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration
8	East Coast petroleum refinery	Field test (submerged aerated) • Flux chamber • Liquid samples • Biological activity testing	1987	EPA/ORD	1 week
9	East Coast synthetic organic chemical manufacturer	Field test (surface aerated) • Liquid samples • Biological activity testing	1986	EPA/ORD	1 week
10	East Coast synthetic organic chemical manufacturer	Field test (surface aerated) • Flux chamber • Liquid samples • Biological activity testing	1986	EPA/ORD	1 week
11	Florida acrylic fiber manufacturer	Field test (surface aerated) • Liquid samples • Biological activity testing	1986	EPA Region IV	2 days
12	Connecticut specialty chemical manufacturer	Field test (covered surface aerated) • Liquid samples • Vent samples	1984	EPA/ORD	1 week
13	Louisiana organic chemical manufacturer	Field test (wastewater treatment plant) • Liquid samples • Ambient air samples	1983	EPA/ORD/ Union Carbide	26 days

TSDF = Treatment, storage, and disposal facility.
ORD = Office of Research and Development.

[a]This table presents a summary of the air emission, liquid concentration, and biological activity testing conducted at TSDF wastewater treatment systems.

TABLE F-4. SUMMARY OF TSDF WASTEWATER TREATMENT SYSTEM MEASURED EMISSION RATES AND MASS TRANSFER COEFFICIENTS[a]

Test site	Area tested, m^2	Total NMHC,[b] Mg/yr	Mass transfer coefficient, x 10^6 m/s								
			Tetralin	2-Ethyl hexanol	2-Ethyl hexylacrylate	Naphthalene	1,2-Dichloroethane	Benzene	Toluene	Ethyl benzene	Total xylene
Site 8											
Aeration tank	1,080	1.2	NA	NA	NA	NA	NA	>47	>280	NA	>240
Site 10											
Aeration tank	320	NA	NA	NA	NA	NA	NA	NA	180	NA	NA
Site 12											
Covered aeration basin	5,940	NA	NA	NA	NA	NA	4.8	30	89	NA	NA
Site 13											
Primary clarifiers	295	NA	230	43	130	88	2.2	19	52	39	NA
Equalization	5,180	NA	NA	NA	NA	NA	16	8.6	38	5.4	NA
Aerated stabilization basins	29,200	NA	NA	0.7	120	NA	62	94	550	60	NA

TSDF = Treatment, storage, and disposal facility.
NA = Not available.
NMHC = Nonmethane hydrocarbon.

[a]This table presents a summary of the calculated mass transfer coefficients for specific constituents from TSDF wastewater treatment system testing. The emission rates used in calculating mass transfer coefficients were obtained from flux chamber measurements (Site 10), vent measurements (Site 12), and ambient measurements and mass balance techniques (Site 13).

[b]Total NMHC emission rates were not measured.

TABLE F-5. SUMMARY OF TSDF LANDFILL TESTING[a]

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration
14	California commercial TSDF	Field test (1 landfill) • Flux chamber • Soil samples	1984	EPA/OAQPS	2 days
6	California commercial TSDF	Field test (2 landfills) • Flux chamber • Soil samples	1984	EPA/OAQPS	2 days
15	Gulf Coast commercial TSDF	Field test (1 landfill) • Flux chamber • Soil samples	1983	EPA/OSW	3 days
16	Northeastern commercial TSDF	Field test (2 landfills) • Flux chamber • Vent samples • Soil samples	1983	EPA/OSW	2 days
7	Northeastern commercial TSDF	Field test (2 landfills) • Flux chamber • Vent samples • Soil samples	1983	EPA/OSW	1 week

TSDF = Treatment, storage, and disposal facility.
OAQPS = Office of Air Quality Planning and Standards.
OSW = Office of Solid Waste.

[a]This table presents a summary of the air emission and soil concentration testing conducted at TSDF landfills.

TABLE F-6. SUMMARY OF TSDF LANDFILL MEASURED EMISSION RATES AND EMISSION FLUX RATES[a]

Test site	Area tested, m^2	Total NMHC, Mg/yr	Emission flux rate, x 10^6 $g/m^2 \cdot s$							
			Acetaldehyde	Methylene chloride	Toluene	1,1,1-Trichloroethane	Tetra-chloroethylene	Total xylene	Styrene	Ethylbenzene
Site 14 Active LF	19,970	54	NA	NA	3.5	2.9	5.2	6.0	NA	1.6
Site 6 Inactive LF	2,370	0.056	NA	0.13	NA	0.071	NA	NA	NA	NA
Active LF										
Temporary storage area	1,470	0.66	NA	0.43	0.073	2.6	0.65	0.65	NA	0.13
Active working area	670	1.4	NA	9.5	NA	32	13	NA	NA	NA
Site 15										
Active LF Cell A	185	0.0048	0.19	NA	<0.063	NA	NA	<0.13	<0.063	<0.063
Site 16										
Active LF-P	7,600	1.9	NA	1.6	0.42	0.21	1.0	0.79	NA	NA
Inactive LF-O	Unknown	0.93	NA	NA	NA	NA	NA	NA	NA	NA
Site 7										
Inactive LF-A										
Vent 2A	Unknown	0.044	NA	NA	NA	NA	NA	NA	NA	NA
Vent 3-2	Unknown	0.0002	NA	NA	NA	NA	NA	NA	NA	NA
Active LF-B										
Flammable cell	2,100	0.70	NA	0.089	0.94	1.7	2.6	0.86	0.20	0.26
Organic cell	4,200	9.6	NA	0.73	3.7	0.45	0.011	32	14	6.7

TSDF = Treatment, storage, and disposal facility.
NA = Not available.
NMHC = Nonmethane hydrocarbon.
LF = landfill.

[a]This table presents a summary of measured total NMHC emission rates and calculated emission flux rates for specific constituents from TSDF landfill testing. Emission rates were measured using flux chamber and vent sampling techniques.

TABLE F-7. SUMMARY OF TSDF LAND TREATMENT TESTING AND TEST RESULTS[a]

Site No.	Test site location	Test description	Test year	Test sponsor	Test description: Waste type	Test description: Application method	Test duration	Waste constituent	Emissions, wt %[b]
17	West Coast	Laboratory simulation	1986-1987	Corporate research facility	API separator sludge	Subsurface (Run 1)	69 d	Oil	40
					API separator sludge	Subsurface (Run 2)	22 d	Oil	11
					Centrifuged and dried API separator sludge	Subsurface (Run 2)	22 d	Oil	1
18	Southwest	Laboratory simulation	1986	EPA/OAQPS	API separator sludge	Surface (Box #1 and 3)[c]	31 d	Oil	5.8
						(Box #2)[d]		Oil	NA
						(Box #4)[e]		Oil	7.4
					IAF sludge	Surface (Box #1 and 3)[c]	31 d	Oil	18.5
						(Box #2)[d]		Oil	NA
						(Box #4)[e]		Oil	22
19	Midwestern refinery	Flux chamber sampling of active land treatment area	1985	EPA/ORD	API separator DAF sludge	Surface	1 wk	Benzene	94[f]
								Toluene	53
								Ethylbenzene	270
								p-Xylene	29
								m-Xylene	51
								o-Xylene	33
								Naphthalene	1
20	West Coast refinery	Flux chamber sampling of active land treatment area	1984	EPA/ORD	DAF/API Float--50-75%, Separator cleanings--20-30%, Miscellaneous oily waste--5%	Surface	5 wk	n-Heptane	60
								Methylcyclohexane	61
								3-Methyl-heptane	52
								n-Nonane	56
								1-Methylcyclohexene	49
								1-Octene	50
								β-Pinene	17
								Limonene	22
								Toluene	37
								p-,m-Xylene	35
								1,3,5-Trimethylbenzene	21
								o-Ethyl-toluene	32
								Total VO	309
								Total oil	1.2
						Subsurface	5 wk	n-Heptane	94
								Methylcyclohexane	88
								3-Methyl-heptane	77
								n-Nonane	80
								1-Methylcyclohexane	76
								1-Octene	74
								β-Pinene	21

(continued)

TABLE F-7 (continued)

Site No.	Test site location	Test description	Test year	Test sponsor	Test description: Waste type	Test description: Application method	Test duration	Waste constituent	Emissions, wt %[b]
20	West Coast refinery (con.)							Limonene	26
								Toluene	56
								p-,m-Xylene	48
								1,3,5-Trimethylbenzene	27
								o-Ethyl-toluene	42
								Total VO	369
								Total oil	1.4
21	Southwest	Laboratory simulation	1983	API/EPA/ ORD	SL-14 (Run No. 18)[h]	Surface	8 h[i]	Oil	9.1
					SL-11 (Run No. 21)			Oil	4.4
					SL-14 (Run No. 24)			Oil	0.02
					SL-11 (Run No. 27)			Oil	0.6
					SL-14 (Run No. 28)			Oil	0.1
					SL-11 (Run No. 32)			Oil	3.0
					SL-11 (Run No. 33)			Oil	2.6
					SL-14 (Run No. 34)			Oil	0.01
					SL-12 (Run No. 35)			Oil	0.9
					SL-11 (Run No. 36)			Oil	78.8
					SL-14 (Run No. 37)			Oil	9.9
					SL-12 (Run No. 40)			Oil	0.7
					SL-11 (Run No. 41)			Oil	2.8
					SL-13 (Run No. 44)			Oil	4.9
					SL-13 (Run No. 45)			Oil	49.9
					SL-13 (Run No. 46)			Oil	7.7
					SL-13 (Run No. 47)			Oil	6.9
					SL-13 (Run No. 48)			Oil	5.0
					SL-13 (Run No. 49)			Oil	9.7
					SL-13 (Run No. 50)			Oil	1.1
					SL-13 (Run No. 51)			Oil	0.47
15	Gulf Coast commercial TSDF	Flux chamber sampling of active land treatment	1983	EPA/ORD	Aged waste[j]	Surface	69 h	Total VO[k]	0.77
							50 h	Benzene	3.91
22	Midwestern refinery	Flux chamber sampling of test plots	1979	API	Sludge from centrifugal dewatering of oily sludges from refinery operations and wastewater treatment	Surface	19.9 h	Oil	0.1[l]
							307 h	Oil	2.5[m]

(continued)

TABLE F-7 (continued)

Site No.	Test site location	Test description	Test year	Test sponsor	Test description: Waste type	Test description: Application method	Test duration	Waste constituent	Emissions, wt %[b]
22	Midwestern refinery (con.)				API separator sludge[n]	Surface	619 h	Oil	13.5[o]
							122 h	Oil	1.1[p]
							520 h	Oil	13.5[q]

TSDF = Treatment, storage, and disposal facility.
API = American Petroleum Institute.
NA = Not applicable
OAQPS = Office of Air Quality Planning and Standards.
ORD = Office of Research and Development.
IAF = Induced air flotation.
DAF = Dissolved air flotation.

[a]This table presents a summary of TSDF land treatment testing and air emission test results. Air emissions were measured in laboratory simulations and by flux chamber sampling of active land treatment areas.

[b]Weight percent is the fraction of the organic waste constituent emitted during the test.

[c]Average of Boxes #1 and #3. Sludge was applied to Box #1 and Box #3 as duplicate tests.

[d]Control--no sludge added.

[e]Mercuric chloride was added to sludge/soil mixture in an attempt to eliminate biological activity.

[f]The values for benzene and the other constituents are an average of results from similar tests done on six plots. The only differences among the tests occurred as a result of uneven sludge application rates. The 95 percent confidence intervals (using Student's distribution) for the mean weight fractions emitted were calculated for each constituent and are as follows:

Benzene 0.58 - 1.30	m-Xylene 0.25 - 0.77
Toluene 0.28 - 0.78	o-Xylene 0.20 - 0.46
Ethylbenzene 1.63 - 3.85	Naphthalene 0.01 - 0.02
p-Xylene 0.12 - 0.46	

The confidence intervals do not take into consideration individual variations that may be associated with all of the measured variables, such as the emission flux rates and rates of application.

[g]The concentration of volatile organics was determined using the purge and trap technique. Analysis was performed on a Varian 3700 gas chromatograph.

[h]Each run number represents a different combination of experimental conditions including sludge type, soil type, sludge loading, soil moisture content, and air relative humidity. Soil and air temperature were constant.

Sludge Type: SL-11 = Emulsions from wastewater holding pond.
SL-12 = DAF sludge.
SL-13 = Mixture of API separator bottoms, DAF froth, and biological oxidation sludge.
SL-14 = API separator sludge.

[i]Each run for which results are reported was 8 hours.

[j]Test was conducted using wastes (primarily petroleum refinery sludges) reported to have been aged about 1 year. Consequently, most of the volatiles are expected to have been emitted prior to the test.

[k]Determined using purge and trap techniques and analyzed using a Varian Model 3700 gas chromatograph.

[l]Test 5. Emissions following application of waste to test plot.

[m]Test 6. Emissions following rototilling at the end of Test 5 on the same test plot.

[n]Waste was weathered for 14 days in open 5-gal buckets in an outdoor open shelter prior to application.

[o]Test 7. Emissions following application of waste to test plot.

[p]Test 8. Emissions following application of waste to test plot.

[q]Test 9. Emissions following rototilling at the end of Test 8 on the same test plot.

TABLE F-8. SUMMARY OF TSDF TRANSFER, STORAGE, AND HANDLING OPERATIONS TESTING AND TEST RESULTS[a]

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Source tested	Test results: Total hydrocarbons,[b] ppm	Test results: Waste constituent	Test results: Emission rate, x 10^6, Mg/yr
6	California commercial TSDF	Ambient monitoring	1984	EPA/OAQPS	1 d	Vicinity of tank storage	0.2	NA	NA
						Drum storage area	0.0	NA	NA
						Drum transfer area	0.0	NA	NA
						PCB building	0.1	NA	NA
23	Eastern commercial chemical conversion and reclaiming facility	Ambient monitoring	1983	EPA/OAQPS	1 wk	Upper drum storage area			
						East side, 0.3 m from drums	60	NA	NA
						East side, 6.1 m from drums	7	NA	NA
						South side, 2.4 m from drums	5	NA	NA
						West side, 2.4 m from drums	5-7	NA	NA
						North side, 1.5 m from drums	10-20	NA	NA
						Lower drum storage area			
						East side, 2.4 m from drums	10-20	NA	NA
						South side, 2.4 m from drums	20-30	NA	NA
						West side, 2.4 m from drums	5	NA	NA
						North side, 2.4 m from drums	7	NA	NA
7	New York commercial TSDF	Vent samples	1983	EPA/OAQPS	1 wk	Drum storage building	NA	Total NMHC	150,000
								Toluene	2,300
								Total Xylene	1,000
								Naphthalene	560
								Methylene chloride	80,000
								1,1,1-Trichloroethane	4,500
								Carbon tetrachloride	3,500
								Tetrachloroethylene	45,000

TSDF = Treatment, storage, and disposal facility.
OAQPS = Office of Air Quality Planning and Standards.
PCB = Polychlorinated biphenyls.
NA = Not available.
NMHC = Nonmethane hydrocarbon.

[a]This table presents a summary of the air emission testing conducted at TSDF transfer, storage, and handling operations.
[b]Ambient measurements by organic vapor analyzer.

TABLE F-9. SUMMARY[a] OF TSDF CONTROLS TESTING

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Test results: Constituent	Test results: Organic removal efficiency, %	Test results: Process vent emissions, Mg/yr
Capture and containment										
12	Northeast specialty chemical manufacturer	Field test • Leak check	1985	EPA/ORD	1 week	Air-supported structure used to control emissions from an aeration lagoon	Leak check survey of the air-supported structure perimeter with a portable hydrocarbon analyzer[b]	NA	NA	NA
Add-on control devices										
24	Pennsylvania NPL Superfund site	Field test • Vent samples • Liquid samples	1985	EPA Region III	4 days	Gas-phase activated carbon bed used to control overhead effluent from air stripper treating leachate	Vent sampling of influent to and effluent from gas-phase activated carbon bed	1,2,3-Trichloropropane	99.999	NA
								(o,m)-Xylene	99.95	NA
								p-Xylene	99.9	NA
								Toluene	99.9	NA
								Ethylbenzene	99.9	NA
								1,2-Dichlorobenzene	99.9	NA
								Other VO	99.9	NA
								Total VO[c]	99.97	NA
12	Northeast specialty chemical manufacturer	Field test • Vent samples • Liquid samples	1985	EPA/ORD	1 week	Gas-phase activated carbon bed used to control vent emissions from air-supported structure covering aeration lagoon[d]	Vent sampling of influent to and effluent from gas-phase activated carbon bed on August 18, 1984	Methylene chloride	51.2	NA
								1,2-Dichloroethane	-47.9	NA
								Benzene	-17.0	NA
								Toluene	41.3	NA
								Chlorobenzene	-2,100.0	NA
								Dichlorobenzene	91.7	NA
								Chloroform	58.3	NA
								NMHC[e]	-15.0	NA
							First set of vent sampling of influent to and effluent from gas-phase activated carbon bed on August 17, 1984	Methylene chloride	-5.0	NA
								1,2-Dichloroethane	-0.5	NA
								Benzene	12.3	NA
								Toluene	-31.6	NA
								Chlorobenzene	-0.8	NA
								Dichlorobenzene	-33.3	NA
								Chloroform	5.5	NA
								NMHC[e]	4.0	NA

See notes at end of table.

(continued)

TABLE F-9 (continued)

Site No.,	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Test results: Constituent	Test results: Organic removal efficiency, %	Test results: Process vent emissions, Mg/yr
12 (con.)							Second set of vent sampling of influent to and effluent from gas-phase activated carbon bed on August 17, 1984	Methylene chloride	0.0	NA
								1,2-Dichloroethane	-34.3	NA
								Benzene	-236.0	NA
								Toluene	-284.0	NA
								Chlorobenzene	-83.3	NA
								Dichlorobenzene	60.0	NA
								Chloroform	1.8	NA
								NMHC[e]	-42.8	NA
							Vent sampling of influent to and effluent from gas-phase activated carbon bed on July 17, 1984	1,2-Dichloroethane	0.0	NA
								Benzene	-8.3	NA
								Toluene	34.3	NA
								Chlorobenzene	-45.8	NA
								NMHC[e]	-8.8	NA
						Gas-phase activated carbon canister used to control breathing and working losses from neutralizer tanks	Vent sampling of influent to and effluent from gas-phase activated carbon canister on August 19, 1984	1,2-Dichloroethane	100.0	NA
								Benzene	100.0	NA
								Toluene	100.0	NA
								Chlorobenzene	100.0	NA
								Chloroform	100.0	NA
								NMHC[e]	53.5	NA
5	Mississippi chemical manufacturing plant	Field test • Vent samples • Liquid samples	1985	EPA/ORD	1 day	Liquid-phase carbon adsorption used to treat steam-stripped wastewater	Liquid sampling of the carbon adsorber influent and effluent	Nitrobenzene	>98.0	NA
								2-Nitrotoluene	>87.0	NA
								4-Nitrotoluene	>82.0	NA
								Total VOC[c]	>95.0	NA
25	West Virginia chemical manufacturing plant	Field test • Vent samples • Liquid samples	1986	EPA/ORD	2 days	Condenser system (primary water-cooled; water-cooled vent condenser) used to recover VO steam-stripped from wastewater	Sampling of the vapor and liquid condensate from the primary condenser and measuring flow rates at these points.	Chloromethane	88.6	NA
								Methylene chloride	90.0	NA
								Chloroform	94.4	NA
								Carbon tetrachloride	89.6	NA
								Total VOC[c]	90.9	NA

See notes at end of table.

(continued)

TABLE F-9 (continued)

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Test results: Constituent	Test results: Organic removal efficiency, %	Test results: Process vent emissions, Mg/yr
26	Texas chemical manufacturing plant	Field test • Vent samples • Liquid samples	1986	EPA/ORD	2 days	Condenser system (primary water cooled; secondary glycol cooled) used to recover VO steam stripped from wastewater	Sampling of the vapor and liquid condensate from the secondary condensor and measuring flow rates at these points	Vinyl chloride	6.0	NA
								chloroethane	47.0	NA
								1,1-Dichloroethene	15.0	NA
								1,1-Dichloroethane	88.0	NA
								1,2-Dichloroethene	84.0	NA
								Chloroform	96.0	NA
								1,2-Dichloroethane	99.5	NA
Volatile organic removal processes										
27	Louisiana chemical manufacturing plant	Field test • Vent samples • Liquid samples	1988	EPA/ORD	2 days	Steam stripper used to strip organics from wastewater	Liquid sampling of stripper feed, bottoms, aqueous condensate, and recovered organic condensate. Vent sampling of primary condenser vent.	Acetone	NA	NA
								Benzene	>99	NA
								Trans-1,2-dichloroethene	NA	NA
								Toluene	>85	NA
								Purgeable organic carbon	>47	NA
								Total VO[c]	>98	NA
25	West Virginia chemical manufacturing plant	Field test • Vent samples • Liquid samples	1986	EPA/ORD	2 days	Steam stripper used to strip organics from wastewater	Liquid sampling of stripper feed, bottoms, and condensate and vent sampling of primary and secondary condenser vents	Chloromethane	>99.98	0.51
								Methylene chloride	>99.999	39.4
								Chloroform	>99.999	12.1
								Carbon tetrachloride	>99.98	4.9
								Trichloroethylene	>99.8	NA
								1,1,2-Trichloroethane	>99.8	NA
28	Texas chemical manufacturing plant	Field test • Vent samples • Liquid samples	1986	EPA/ORD	2 days	Steam stripper used to strip organics from wastewater	Liquid sampling of the stripper influent and effluent and from the overhead aqueous and organic condensate. Vent sampling of secondary condenser vent	1,2-Dichloroethane	99.998	11
								Chloroform	96.0	3.5
								Benzene	>95.0	NA
								Carbon tetrachloride	>99.4	NA
								Chlorobenzene	97.0	NA
								Chloroethane	>99.9	1.4
								1,1-Dichloroethane	>99.9	0.41
								1,1-Dichloroethene	>99.8	0.98
								1,2-Dichloroethene	>99.9	0.31
								Methylene chloride	>99.2	NA
								Tetrachloroethene	>99.3	NA
								1,1,2-Trichloroethane	>99.9	NA
								Trichloroethene	>99.8	NA
								Vinyl chloride	>99.9	2.6
								Total VO[c]	>99.8	20

See notes at end of table.

(continued)

TABLE F-9 (continued)

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Test results: Constituent	Test results: Organic removal efficiency, %	Test results: Process vent emissions, Mg/yr
5	Mississippi chemical manufacturing plant	Field Test • Vent samples • Liquid samples	1985	EPA/ORD	1 day	Steam stripper used to strip organics from wastewater from production primarily of nitrated aromatics and aromatic amines	Liquid sampling of the stripper influent and effluent and from the overhead aqueous and organic condensates. Vent sampling of condensate tank vent	Nitrobenzene	91.4	<0.0011
								2-Nitrotoluene	96.7	<0.0011
								4-Nitrotoluene	96.9	<0.0011
								Total VOC	92.0	<0.0033
28	Organic solvent recycling plant	Field test • Vent samples • Liquid samples	1984	EPA/ORD	3 days	Steam stripper used for organic solvent reclamation from contaminated organics generated by the chemical, paint, pharmaceutical, plastics, and heavy manufacturing industries	Sampling during four batches. Liquid sampling of stripper influent, condensate, miscible solvent tank, and recovered VO storage tank. Vent sampling of condenser vent. Batch 1: aqueous xylene	Acetone	91.0	NA
								Isopropanol	99.6	0.0045
								Methyl ethyl ketone	96.0	0.019
								1,1,1-Trichloroethane	87.0	0.0042
								Tetrachloroethane	96.0	0.0023
								Ethyl benzene	99.1	0.0039
								Toluene	99.6	0.016
								Xylene	99.5	0.0085
								Total VOC	99.4	0.058
							Batch 2: 1,1,1-trichloroethane/oil	1,1,1-Trichloroethane	99.8	0.0019
								Methyl ethyl ketone	100.0	0.077
								Total VOC	99.8	0.079
							Batch 3: aqueous 1,1,1-trichloroethane	1,1,1-Trichloroethane	94.0	NA
								Methyl ethyl ketone	99.0	NA
								Acetone	99.0	NA
								Ethyl benzene	74.0	NA
								Isopropanol	<85.0	NA
								Total VOC	94.0	NA
							Batch 4: aqueous mixed solvents	Acetone	99.98	NA
								1,1,1-Trichloroethane	90.0	NA
								Total VOC	96.0	NA

See notes at end of table.

(continued)

TABLE F-9 (continued)

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Test results: Constituent	Test results: Organic removal efficiency, %	Test results: Process vent emissions, Mg/yr
29	Chemical manufacturing plant	Field test • Vent samples • Liquid samples	1984	EPA/ORD	2 days	Steam stripper used to remove VO, especially methylene chloride, from aqueous streams	Liquid sampling of stripper influent, effluent, and organic overhead condensate. Vent sampling from product receiver tank vent	Methylene chloride	>99.99	1.4
								Chloroform	91.0	0.013
								Carbon tetrachloride	NA	0.0047
								Total VO[c]	99.8	1.4
24	Pennsylvania NPL Super-Fund site	Field test • Vent samples • Liquid samples	1985	EPA Region III	4 days	Air stripper used to treat leachate from closed lagoons	Test yielding highest VO removal efficiency.[f] Liquid samples of air stripper influent and effluent	1,2,3-Trichloropropane	>98	<0.0000013
								(o,m)-Xylenes	>96	0.000023
								p-Xylene	>88	0.000016
								Toluene	NA	0.000014
								Aniline	63	NA
								Phenol	>53	NA
								2-Methylphenol	70	NA
								4-Methylphenol	>53	NA
								Ethylbenzene	NA	0.0000038
								1.2-Dichlorobenzene	>71	0.0000012
								1,2,4-Trichlorobenzene	>68	NA
								Other VO	30	0.0000051
								Total VO[c]	>99	0.000064
							Test under standard operating conditions.[g] Liquid samples of air stripper influent and effluent	1,2,3-Trichloropropane	6.9	NA
								(o,m)-Xylenes	57	NA
								p-Xylene	46	NA
								Toluene	46	NA
								Aniline	38	NA
								Phenol	52	NA
								2-Methylphenol	29	
								1,4-Dichlorobenzene	40	NA
								1,2-Dichlorobenzene	51	NA
								bis(2-Chloroisopropyl) ether	>62	NA
								2,4-Dimethylphenol	34	NA
								1,2,4-Trichlorobenzene	52	NA
								Ethylbenzene	89	NA

See notes at end of table.

(continued)

TABLE F-9 (continued)

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Test results: Constituent	Test results: Organic removal efficiency, %	Test results: Process vent emissions, Mg/yr
24 (con.)								Chlorobenzene	67	NA
								Ethane,1,1-oxybis[2-ethoxy]	4.1	NA
								Other VO	45	NA
								Total VO[c]	25	NA
30	Thin-film evaporator manufacturing plant	Pilot-scale tests • Vent samples • Liquid samples	1986	EPA/HWERL	1 week	Thin-film evaporator used on petroleum refinery wastes	Liquid sampling of evaporator feed, bottoms, and condensate. Vent samples collected, but vent gas flow rate not measured	Benzene	99.76	NA
								Toluene	99.96	NA
								Ethylbenzene	99.78	NA
								Styrene	99.25	NA
								m-Xylene	99.75	NA
								o,p-Xylene	99.74	NA
								Phenol	NA	NA
								Benzyl alcohol	NA	NA
								2-Methylphenol	NA	NA
								4-Methylphenol	NA	NA
								2,4-Dimethylphenol	NA	NA
								bis(2-Ethylhexyl) phthalate	NA	NA
								Naphthalene	96.86	NA
								2-Methylnaphthalene	87.47	NA
								Acenaphthylene	33.33	NA
								Acenaphthene	>90	NA
								Dibenzofuran	89.48	NA
								Fluorene	86.50	NA
								Phenanthrene	75.21	NA
								Anthracene	NA	NA
								Pyrene	74.38	NA
								Benzo(a)anthracene	74.06	NA
								Chrysene	65.14	NA
								Di-n-octylphthalate	NA	NA
								Benzo fluoranthene[d]	51.11	NA
								Benzo(a)pyrene	71.28	NA
31	Texas solvent recycling facility	Field test • Vent samples • Liquid samples	1986	EPA/ORD	4 days	Batch thin-film evaporator used to treat waste paint and lacquer thinners	Liquid samples of evaporator feed stream, bottoms, and condensate. Gas samples collected but vent velocities not measured	Acetone	99	NA
								Ethyl acetate	>45	NA
								Methyl isobutyl ketone	80	NA
								n-Butyl alcohol	>75	NA
								Toluene	82	NA
								Methyl ethyl ketone	84	NA
								Isopropanol	>96	NA
								Total VO[c]	74	NA

See notes at end of table.

(continued)

TABLE F-9 (continued)

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Test results: Constituent	Test results: Organic removal efficiency, %	Test results: Process vent emissions, Mg/yr
32	Organic solvent recycling plant	Field test • Vent samples • Liquid samples	1984	EPA/ORD	1 day	Thin-film evaporator used in reclamation and recycle of organic solvents from the chemical, plastics, paint, adhesive film, electronics, and photographic industries	Liquid sampling of evaporator feed, bottoms, and condensate. Vent sampling of condenser vent.	Acetone	76	NA
								Xylene	30	NA
								1,1,1-Trichloroethane	82	NA
								Toluene	82	NA
								Tetrachloroethylene	54	NA
								Trichloroethylene	93	NA
								Freon TF	72	NA
								Ethylbenzene	<85	NA
								Total VOC	73	NA
23	Eastern commerical chemical conversion and reclaiming facility	Field test • Vent samples • Liquid samples	1984	EPA/ORD	1 day	Thin-film evaporator used to process organic wastes from the furniture, chemical, dry cleaning, and paint industries	Liquid sampling of evaporator influent, bottoms, and condensate. Vent sampling of vacuum pump vent	Methylene chloride	99.1	NA
								Chloroform	>99.99	NA
								1,1,1-Trichloroethane	>99.5	NA
								Toluene	<85.0	NA
								Freon TF	80	NA
31	Texas solvent recycling facility	Field test • Vent samples • Liquid samples	1986	EPA/ORD	4 days	Azeotropic steam injection distillation unit used to purify chlorinated solvents	Field testing on two batches. Liquid sampling of waste feed, final injection kettle residue, and overhead organic and aqueous condensates. Gas samples collected but vent gas velocities not measured. Batch 1: methylene chloride as major constituent	Tetrachloroethylene	89	NA
								Methylene chloride	92	NA
								Carbon tetrachloride	>80	NA
								Trichlorotrifluoroethane	>87	NA
								Xylenes	38	NA
								Ethyl acetate	82	NA
								Isopropanol	36	NA
								Total VOC	76	NA
							Batch 2: 1,1,1-trichloroethane as major constituent	Trichloroethylene	>21	NA
								Methylene chloride	>51	NA
								1,1,1-Trichloroethane	91	NA
								Trichlorotrifluroethane	>51	NA
								Isopropanol	>12	NA
								Total VOC	91	NA

See notes at end of table.

(continued)

TABLE F-9 (continued)

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Test results: Constituent	Test results: Organic removal efficiency, %	Test results: Process vent emissions, Mg/yr
33	Organic chemical recovery plant	Field test • Vent samples • Liquid samples	1984	EPA/ORD	2 days	Batch distillation used in reclamation of contaminated solvents and other chemicals from the chemical, paint, ink, recording tape, adhesive film, automotive, airlines, shipping, electronic, iron and steel, fiberglass, and pharmaceutical industries	Field testing on two units. Liquid sampling of charge to reboiler, final aqueous residue from reboiler, and final overhead condensate. Vent sampling of condenser, receiver, and product accumulator vents, Unit 1	Methyl ethyl ketone	>99.97	2.5
								2,2-Dimethyl oxicane	>99.8	0.52
								methanol	>99.7	0.30
								Methylene chloride	>99.7	0.26
								Isopropanol	>99.5	0.16
								Carbon tetrachloride	>99.4	0.14
								1,1,1-Trichloroethane	29.0	0.017
								Other VO	>98.0	0.17
								Total VO[c]	>99.0	4.1
							Unit 2	Acetone 99.7	0.074	
								Trichloroethane	>99.9	0.0034
								1,1,1-Trichloroethane	>99.7	0.00098
								Toluene	>99.7	0.00095
								Methyl ethyl ketone	>99.6	0.00080
								Isopropanol	98.0	0.00015
								Aromatics	97.0	0.00010
								Total VO[c]	99.8	0.080

TSDF = Treatment, storage, and disposal facility.
ORD = Office of Research and Development.
NMHC = Nonmethane hydrocarbon.
VO = Volatile organics.

[a]This table presents a summary of the results of tests of control technologies applied to TSDF emission sources. For sources with available test measurements, estimated removal efficiencies and process vent emissions are presented.

[b]Measured total hydrocarbon concentration ranged from 2 to 3 ppmv near the carbon adsorber to 30 to 40 ppmv at the escape hatch. Plant personnel estimated total leakage at 0.14 m^3/s (300 cfm).

[c]Total VO removal efficiency represents weighted average removal efficiency for the listed constituents.

[d]Beds originally designed for odor control, specifically for removal of orthochlorophenol.

[e]Removal efficiency is for total nonmethane hydrocarbon and is not limited to the listed constituents. Only major constituents (in terms of relative concentrations) are presented.

[f]Highest VO removal from water was obtained when the influent water rate was throttled down to 1,140 kg/h (2,513 lb/h) and the air flow correspondingly increased to 4.8 m^3/min (170 ft^3/min), giving the highest air:water ratios observed during testing.

[g]Under standard operating conditions at the time of the test, the water flow rate was 8,200 kg/h (18,078 lb/hr), and the air inlet rate was unknown but expected to be less than 1.7 m^3/min (60 ft^3/min).

TABLE F-10. SURFACE IMPOUNDMENT DIMENSIONS AT TSDF SITE 1

Impoundments	Dimensions, m[a]	Pitch (hor:vert)
2	36 x 30 x 4.6	2:1
6	61 x 33 x 4.6	2:1
8	71 x 72 x 5.2	1:1

TSDF = Treatment, storage, and disposal facility.

[a]Length and width dimensions refer to the bottom of the ponds.

Treated wastewater from Pond 6 is then pumped to Pond 8. Pond 8, which has a capacity of approximately 26,000 m^3, acts as a holding pond prior to the aerated WWT unit. Effluent from the WWT system is then pumped back to Pond 8 so that the only route for aqueous removal is evaporation.

Grab samples of wastewater for chemical analysis were collected on April 7, 1987, in 1-L amber glass bottles with Teflon-lined screw caps and in 40-mL zero-headspace, Teflon-lined, septum volatile organic analysis (VOA) vials. Because no "anaerobic zones" were identified in Ponds 2 or 6 (i.e., no dissolved oxygen [DO] < 1.0 mg/L were measured), only one set of grab samples was collected from these impoundments. Samples were taken from two different locations within Pond 8: one in the aerobic zone near the surface of the wastewater, and one in the anaerobic zone near the bottom of the lagoon.

The samples were analyzed for purgeable organics according to EPA Method 624[2] and for base/neutral and acid extractables according to EPA Method 625.[3] Data for the purgeable organics identified in the samples are presented in Table F-11.

The extractable organic analysis included 56 compounds. The data for the compounds present in the wastewater samples are presented in Table F-12.

In addition to the chemical analysis samples, samples were obtained at each of the sampling points for biological activity testing. Due to the extremes in pH found in Ponds 2 and 6 (0.5 and 11.5, respectively), the samples from these ponds were not expected to be biologically active. Only a limited amount of wastewater was collected from these ponds to document the presence or absence of biological activity. At Pond 2, approximately 3.8 L of wastewater was collected in a 9.5-L plastic container. At Pond 6, two 1-L amber glass bottles were filled using the residual wastewater left in the bucket after filling the chemical analysis sample containers. Samples for biological testing were collected from near the surface and from near the bottom of Pond 8. The biological testing samples were 9.5 L in volume and were collected in 9.5-L plastic containers.

Microscopy studies were employed to confirm the presence of microorganisms in the wastewater. Both wet drop slides and gram-stained slides

TABLE F-11. ANALYSES OF SAMPLES TAKEN AT SITE 1 SURFACE IMPOUNDMENTS: PUREGEABLE ORGANICS[a]

Constituent	Concentration, μg/L				
	Pond 2 aerobic sample	Pond 6 aerobic sample	Pond 8 duplicate aerobic samples		Pond 8 anaerobic sample
Methylene chloride	1,850	46[b]	47[b]	36[b]	44[b]
Chloroform	880[b]	22[b]	2.3[b]	2.5[b]	<50
1,1,1-Trichloroethane	16,000	30[b]	<50	<50	<50
Tetrachloroethene	<50	<50	22[b]	24[b]	<50
1,1,2,2-Tetrachloroethane	<50	15[b]	<50	<50	<50
Benzene	<50	9[b]	<50	<50	<50
Toluene	2,070	33[b]	43[b]	46[b]	47[b]
Ethyl benzene	<50	11[b]	12[b]	15[b]	<50
Chlorobenzene	42[b]	7[b]	2[b]	3[b]	3[b]
Acetone[c]	35,000	5,450	4,500	4,200	4,100
Isopropanol[c]	156,000	8,400	4,200	3,200	3,200
1-Butanol[b,c]	71,300	510	<50	<50	<50
Thiobismethane[c]	<50	<50	1,300	1,300	1,500
Freon 113[c]	<50	<50	40[b]	23[b]	49[b]
Methyl ethyl ketone[c]	27,000	210	510	490	620
Total xylenes[c]	1,140	<50	47[b]	49[b]	<50

TSDF = Treatment, storage, and disposal facility.

[a]Determined by EPA Method 624.

[b]Indicates concentration is below the reportable quantitation limit. These compounds were positively identified, but the accuracy of quantitation is not guaranteed within 30 percent.

[c]Indicates compounds identified that are not Method 624 target analytes. These compounds are not quantitated according to Method 624; their absolute accuracy is not guaranteed. However, the relative concentrations for any one compound should be consistent (i.e., should show correct relative trends).

TABLE F-12. ANALYSES OF SAMPLES TAKEN AT SITE 1 SURFACE IMPOUNDMENTS: EXTRACTABLE ORGANICS[a]

Constituent	Concentration, μg/L				
	Pond 2 aerobic sample	Pond 6 aerobic sample	Pond 8 duplicate aerobic samples		Pond 8 anaerobic sample
Bis (2-chloroisopropyl) ether	17,600	76[b]	68[b]	<200	148[b]
Bis (2-ethylhexyl) phthalate	6,560	78[b]	43[b]	<200	<200
Isophorone	72,800	5,600	34[b]	75[b]	160[b]
2-Nitrophenol	<1,000	660	670	490	800
N-Nitrosodiphenylamine	<4,000	35[b]	35[b]	40[b]	137[b]

TSDF = Treatment, storage, and disposal facility.

[a]Determined by EPA Method 625.

[b]Indicates concentration is below the reportable quantitation limit. These compounds were detected, but the accuracy of quantitation is not guaranteed within 30 percent.

were employed. No motile organisms were observed using the wet drop slides; a few stalks of algae were observed in the samples collected from Ponds 6 and 8. Numerous bacteria were observed in all the wastewater samples using gram-stained slides. The bacteria observed were predominantly gram-negative, with scattered gram-positive bacteria visible.

From the microscopy studies, all wastewater samples apparently contained microorganisms. Pond 8 appeared to be the most heavily populated, and Pond 6 appeared to be the least populated. No other studies were performed to further identify the microorganisms.

The presence of aerobic biological activity was determined by the ability of the microorganisms to remove oxygen from the wastewater. Two experiments were employed to measure the oxygen consumption rate of the microorganisms.

The first experiment performed was the dissolved oxygen (DO) depletion experiment. The procedure employed was as follows. A wide-mouth, amber glass, 0.5-L bottle was filled with the wastewater sample and allowed to come to thermal equilibrium. Air was then bubbled through the sample for approximately 5 min to raise the initial DO concentration. A magnetic stir bar was added to the sample bottle. The lid, fitted with a DO probe, was secured allowing the wastewater to overflow in order to ensure zero headspace within the bottle. The sample was stirred using a magnetic stirrer, and the DO concentration was recorded with time. The DO depletion experiments were approximately 1 day in duration. A parallel DO depletion experiment was performed on each of the wastewater samples by adding 0.5 g of biocide (mercuric acetate) to the 500-mL sample prior to testing. The parallel samples (denoted as killed) were used to distinguish between biological oxygen consumption and chemical oxygen consumption.

The second oxygen uptake rate experiment employed a manometric biochemical oxygen demand (BOD) apparatus and was consequently termed the BOD-type experiment. The procedure employed was as follows. To a 0.5-L amber glass respirometry bottle, 350 to 400 mL of sample was quantitatively added. The bottle was then placed on a magnetic stirring plate and slowly agitated. The respirometry bottle lid has a tube fitting to allow the bottle to be connected to a mercury manometer and a sealing nipple that

houses lithium hydroxide. During biodegradation, the lithium hydroxide absorbs the carbon dioxide produced so that the consumption of oxygen results in a decrease in the total pressure of the system according to the ideal gas law. The pressure drop resulting from aerobic (oxygen consuming) biological activity was measured with the mercury manometer as a function of time. The rate of oxygen consumption in these experiments was sufficiently slow so that the oxygen transfer rate was not limiting. The BOD-type experiments were longer in duration than the DO depletion experiment and were performed over a 1- to 2-week period.

There was negligible oxygen consumption in the poisoned wastewater samples collected from Ponds 6 and 8, indicating that the oxygen consumption observed by these samples was biological in nature. The oxygen consumption of the poisoned sample from Pond 2, on the other hand, was nearly identical to the oxygen consumption of the sample with no biocide added. This indicated that the oxygen consumption exhibited by this sample was chemical in nature, as would be expected by the biologically prohibitive pH (pH = 0.5) measured in Pond 2. Plant personnel stated that this low pH was not indicative of normal operating conditions for Pond 2.

The component-specific rate determinations were designed to permit organic removal due to biodegradation while limiting their removal by air stripping. The calculated rate constants are summarized in Table F-13. In general, the first-order rate constants typically fit the data better than the zero-order rate constants as judged by the correlation coefficient of the regression analysis. This is probably a consequence of the low initial concentrations for most of the volatile organics studied. The rate constants for a single compound, as calculated for the two different ponds, are in fair agreement because they are within a factor of 2 or 3. Each zero-order rate constant is at least two orders of magnitude less than the biodegradation rate constants typically reported from laboratory experiments employing single-component systems. The low concentrations, and the presence of the multiple, potentially competing substrates, are among the reasons for the low zero-order biodegradation rates observed.

F.1.1.2 Site 2.[4] Site 2 is primarily engaged in the treatment and disposal of dilute (less than 10 percent organic) aqueous wastes generated

TABLE F-13. SUMMARY OF CONSTITUENT-SPECIFIC BIODEGRADATION RATES IN SAMPLES TAKEN AT SITE 1 SURFACE IMPOUNDMENTS

Constituent	Zero-order biorates,[a] x 10^3 mg/g-h		First-order biorates, x 10^3 L/h	
	Pond 6	Pond 8	Pond 6	Pond 8
Chloroform	2.65	0.19	5.77	2.46
Methylene chloride	3.34	2.04	1.73	0.88
Toluene	3.74	4.21	4.44	4.42
Acetone	684	318	22.8 10.9 22.9	2.10 2.29 1.50
Isopropanol	532	222	1.38 0.20 1.92	1.20 1.83 1.00
Benzene	0.89		3.06	
Ethyl benzene	1.43		9.86	
Methyl ethyl ketone	22.4	38.7	3.73	2.34
1,1,1-Trichloroethane	137		13.7	
Trichloroethene	1.63		6.57	

TSDF = Treatment, storage, and disposal.

[a]The zero-order biodegradation rate constants were normalized for the biomass concentration as measured by the volatile suspended solids content. The rate constants reported for Pond 6 were based on the biomass concentration measured in Pond 8 (i.e. 16 mg/L).

by industry and commercial TSDF. The organics in these streams are either unsuitable for recycling or are too low in concentration to make recovery economically attractive. A number of treatment technologies are employed at Site 2, including neutralization, distillation, air stripping, chemical oxidation, incineration, and solar evaporation. The overall processing objective is to reduce the VO concentration in the aqueous streams to a level that is acceptable for final disposal of the waste in evaporation ponds.

Approximately 227 million L of wastewater is pumped to the evaporation ponds for disposal each year. At the time of the site visit, the B-Pond was the receiving pond. From the B-Pond, the wastewater was pumped to the C-Pond. The B- and C-Ponds each cover approximately 81,000 m^2 and have a depth of 1.2 to 1.8 m. Appropriate piping is in place to allow the transfer of liquid between any two ponds at the disposal site to ensure adequate freeboard and to maximize the surface area for evaporation. There is no discharge from the site; each pond is dredged once a year to remove accumulated solids.

Two samples were taken at different places in the B-Pond on September 23, 1986. One sample each was taken from Ponds C, D, and E. The samples were analyzed for purgeable organic priority pollutants by EPA Method 624 and extractable organic priority pollutants by EPA Method 625. Concentration data are presented in Table F-14 for purgeable organics. No extractable organic priority pollutants were found in any of the samples.

In addition to the chemical analysis samples, samples were obtained at each of the sampling points for biological activity testing. These samples were collected in 9.5-L plastic containers.

Microscopy studies were initially employed to confirm the presence of microorganisms in the wastewater. There were no motile microorganisms observed using wet drop slides. Pond B(W) and B(SE) samples appeared to have agglomerations of coccoid blue-green algae. The abundance of inorganic solids, however, especially in the D-Pond sample, hindered the wet drop slide studies. Both filamentous and nonfilamentous bacteria were observed using gram-stained slides of Pond B(W), B(SE), C, and D samples. Both gram-positive bacteria (stained purple) and gram-negative bacteria

TABLE F-14. PURGEABLE ORGANICS ANALYSES[a] FOR WASTE SAMPLES TAKEN AT SITE 2 SURFACE IMPOUNDMENTS

Constituent	Concentration, μg/L				
	B-Pond (SE corner)	B-Pond (W side)	C-Pond	D-Pond	E-Pond
Acetone[b]	1,700	1,600	54	2,800	16,000
Methylene chloride	35[c]	56[c]	BQL[e]	11,000	12,000
Chloroform	BQL[d]	BQL[d]	BQL[e]	110	BQL[c]
1,2-Dichloroethane	BQL[d]	BQL[d]	BQL[e]	120	BQL[c]
1,1,1-Trichloroethane	BQL[d]	BQL[d]	BQL[e]	1,300	760
Tetrachloroethane	BQL[d]	BQL[d]	BQL[e]	130	640[c]
Freon 113[b]	BQL[d]	BQL[d]	BQL[e]	550	370
Toluene	35[c]	40[c]	7.5[c]	890	3,000
Ethyl benzene	BQL[d]	BQL[d]	BQL[e]	170	100
Total xylenes[b]	56[c]	70[c]	BQL[e]	820	430
Benzene	BQL[d]	BQL[d]	BQL[e]	60[c]	69[c]

TSDF = Treatment, storage, and disposal facility.

[a]Determined by EPA Method 624.

[b]Indicates nontarget compounds quantitated using a response factor from a single-point calibration.

[c]Compound identified below strict quantitation limit; accuracy of reported concentration not ensured to be within 30 percent.

[d]Below method quantitation limit of 100 μg/L.

[e]Below method quantitation limit of 10 μg/L.

(stained red) were observed. No cell cultures were grown to characterize the bacteria further.

The presence of aerobic biological activity was determined by the ability of the microorganisms to remove oxygen from the wastewater. Two experiments were performed to measure the oxygen consumption rate of the microorganisms.

The first oxygen uptake experiment performed was the DO depletion experiment. The general procedure employed was as follows. Two wide-mouth, amber glass, 0.5-L bottles were filled with the wastewater sample being tested. To one of these bottles, approximately 0.5 g of mercuric acetate was added to arrest all biological activity. Both samples were left at room temperature (23 °C) for several hours to ensure that thermal equilibrium of both samples had been reached and that effective poisoning of the "killed" sample had been accomplished. Before testing, a magnetic stir bar was added to the sample bottle, and air was bubbled through the wastewater for several minutes to raise the initial DO concentration. The bottle lid, which was fitted with a DO probe, was then secured to the bottle allowing the wastewater to overflow to ensure zero headspace within the bottle. To test, the sample was stirred using a magnetic stirrer, and the DO concentration was recorded with time. The DO uptake experiments were typically short in duration (less than 1 hour) and provided an estimate of the initial oxygen utilization rate.

The second oxygen uptake rate experiment performed was similar to a BOD determination. To a 0.5-L amber glass respirometry bottle, 250 mL of sample was added. The respirometry bottle lid has a tube fitting to allow the bottle to be connected to a mercury manometer. A T-connector was inserted in the manometer tubing; lithium hydroxide was poured in the side tube to absorb produced carbon dioxide, and the side tube was sealed. The bottle was then clamped in a wrist-action shaker and sufficiently agitated to ensure that oxygen transfer was not rate limiting. The pressure drop resulting from aerobic (oxygen-consuming) biological activity was measured with the mercury manometer as a function of time. Duplicate runs were performed. The BOD-type experiments were typically long term in nature (on the order of days) and provided an estimate of the average potential oxygen utilization rate.

A summary of oxygen utilization rates for samples from Ponds B, C, and D is given in Table F-15.

F.1.1.3 Site 3.[5] Site 3 operates two separate manufacturing facilities, a petroleum refinery and a lubricating oil plant on the Gulf Coast. The refinery produces various grades of gasoline and fuel oils. The lubricating oil plant refines crude oil fractions from the refinery to the lubricating oil base, which is blended into lubricating oil at other sites. The two facilities have separate WWT systems and discharge through separate outfalls to rivers.

Process wastewater enters the refinery WWT system at a flow rate of approximately 18,900 L/min. The WWT system consists of neutralization, equalization, flocculation, dissolved air flotation (the float is pumped to a sludge tank), aeration, and clarification (the bulk of the underflow is recycled to the aeration basin, excess sludge is pumped to an aerobic digester, and the overflow passes to the refinery polishing pond).

The lube oil plant's process wastewater stream flows intermittently to a retention/neutralization basin. The neutralized wastewater along with another "oily water" stream and cooling water flows to an American Petroleum Institute (API) separator. The flow from the API separator is approximately 7,600 L/min and passes to dissolved air flotation, equalization, aeration, and clarification. The clarifier overflow then flows through an open channel to the polishing pond, which also receives storm water runoff from a holding basin.

Preliminary sampling of the polishing ponds was performed on August 27, 1986, to determine the wastewater composition and to evaluate the potential for biodegradation and air emissions. The refinery polishing pond has a depth of 1.2 to 3 m, a flow rate of 27 million L/d, and a retention time of 1.7 d. The lube oil polishing pond has a depth of approximately 1.2 to 1.5 m, a flow rate of 11 million L/d, and a retention time of 4 d. Both polishing ponds discharge to rivers.

Two samples, one near the bottom and the second approximately 7.6 cm below the surface at the same point, were collected from each polishing pond for chemical analysis. Each sample was pumped through tygon tubing into an amber glass bottle with Teflon-lined cap. The refinery polishing

TABLE F-15. SUMMARY OF RESULTS FOR ALL OXYGEN UPTAKE EXPERIMENTS PERFORMED WITH SAMPLES TAKEN AT SITE 2 SURFACE IMPOUNDMENTS[a]

Pond sample and preservation status	Experimental oxygen uptake rate, mg/L-h[b]	
	DO depletion	BOD-type
B(W) (normal)	7.19	34.9
B(W) (killed)	0.227	
B(SE) (normal)	12.1	33.8
B(SE) (killed)	0.504	
C (normal)	2.85	5.75
C (killed)	0.242	
D (normal)	38[c]	143
D (killed)	38[c]	

TSDF = Treatment, storage, and disposal facility.
DO = Dissolved oxygen.
BOD = Biochemical oxygen demand.

[a]The purpose of this table is to demonstrate noncompound-specific oxygen uptake rates determined by two methods and to demonstrate the biological (as compared with chemical) nature of the oxygen demand.

[b]Oxygen uptake rates were determined by using a least squares linear regression on the data.

[c]The DO depletion experiment was modified as explained in the text.

pond sampling point was at the edge of the pond opposite the inlet and about halfway along the length. The lube oil plant polishing pond samples were collected at a point 1.8 m from the edge of a small pier near the inlet end of the pond. In addition, a sample was obtained from each pond at the same sampling point for biodegradation rate studies. These were pumped into Nalgene containers.

The chemical analysis for purgeable organics was done in accordance with EPA Method 624. The analysis involved a gas chromatography-mass spectrometry (GC-MS) search for 31 specific organic priority pollutants. None of these compounds was found in any of the four chemical analysis samples above a minimum detection limit of 10 μg/L. The samples also were analyzed for acid, base, and neutral extractable compounds by EPA Method 625. This analysis involved a search for 81 specific organic compounds, none of which was found at concentrations above the minimum detection level.

Because no priority pollutants were found in the chemical analysis samples above the minimum detection limit, no compound-specific biodegradation rates were obtained. However, the presence of aerobic biological activity was determined by the ability of the microorganisms to remove oxygen from the wastewater. A wide-mouth, amber glass, 0.5-L bottle was filled with wastewater from each biodegradation rate sample and allowed to come to thermal equilibrium. Air then was bubbled through the sample for approximately 5 min to raise the initial DO concentration. A magnetic stir bar was added to the sample bottle. The lid, fitted with a DO probe, was secured allowing the wastewater to overflow in order to ensure zero headspace within the bottle. The sample was stirred using a magnetic stirrer, and the DO concentration was recorded with time. Figures F-1 and F-2 present the results of the DO depletion experiments on the samples obtained near the surfaces of the refinery polishing pond and the lube oil plant polishing pond, respectively. In addition, on the basis of the measured oxygen uptake rate, the amount of biomass was estimated to be 0.0031 g/L in the refinery polishing pond and 0.0014 g/L in the lube oil polishing pond.

F.1.1.4 Site 4.[8] Site 4 is a chemical plant located in a southwestern State. The plant produces aldehydes, glycols, glycol ethers,

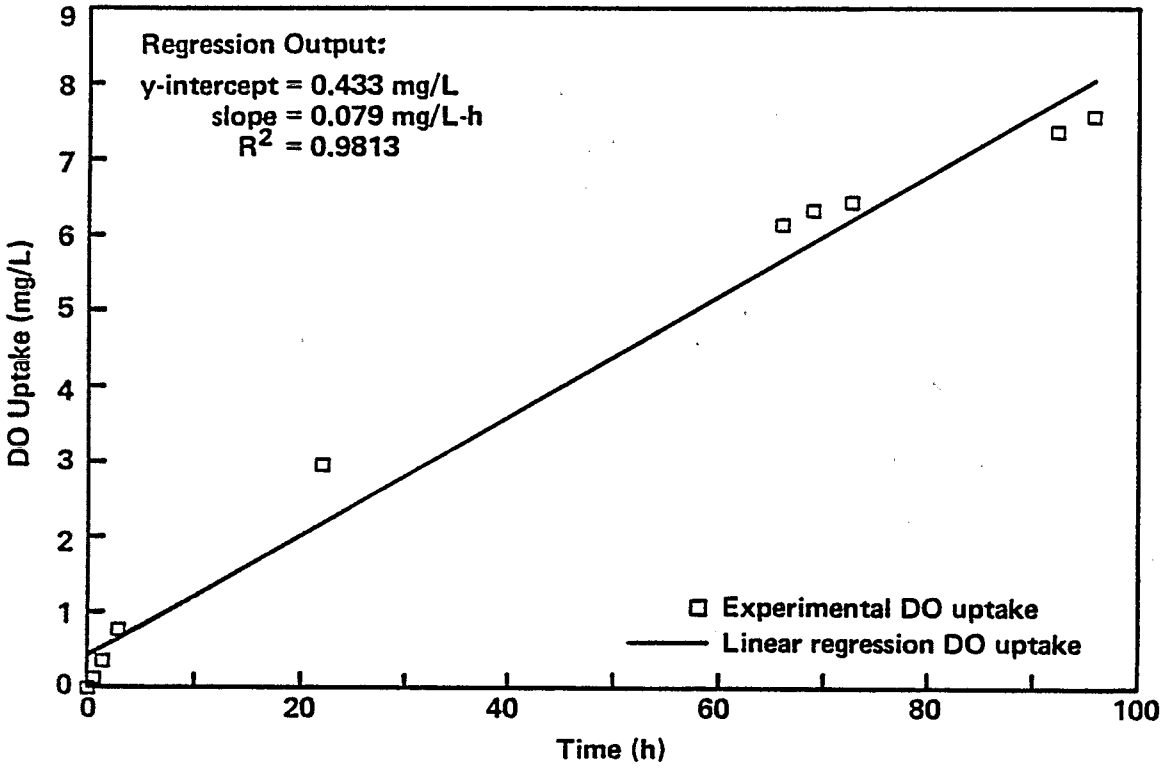

Figure F-1. TSDF Site 3 refinery polishing pond dissolved oxygen uptake curve.[6]

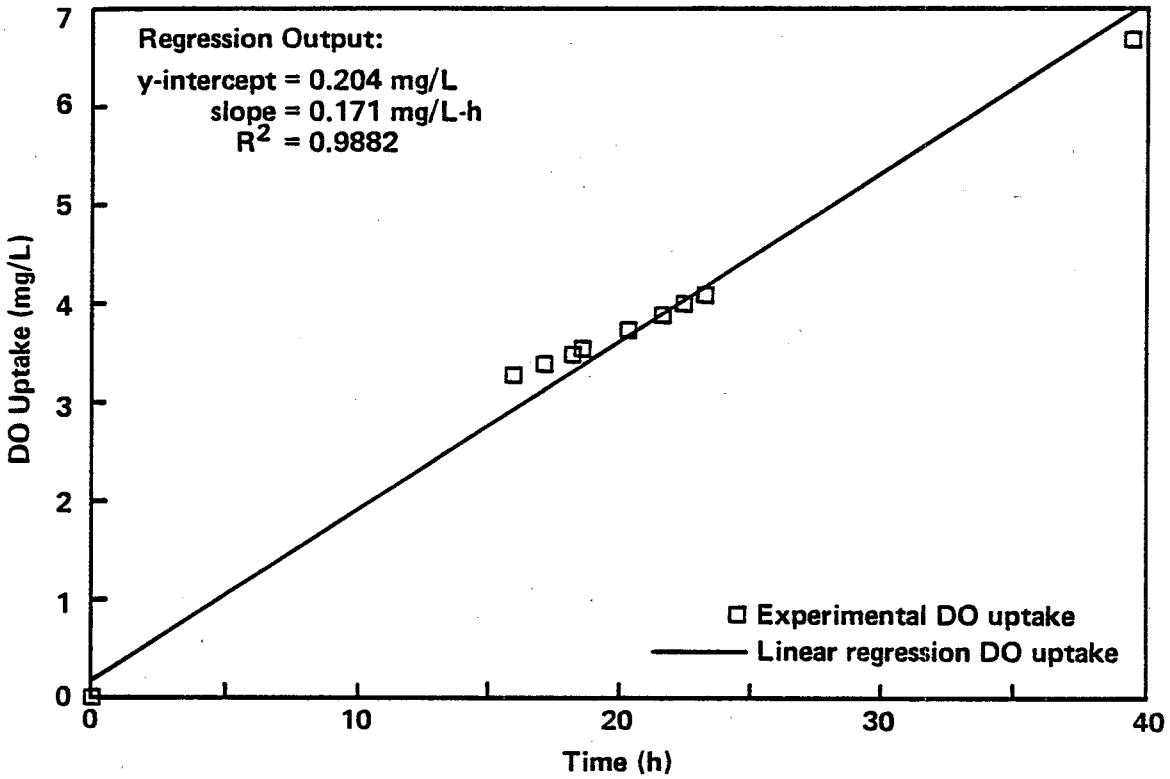

Figure F-2. TSDF Site 3 lube oil plant polishing pond dissolved oxygen uptake curve.[7]

nitriles, esters, and numerous other products. Manufacturing wastewater is treated in a series of seven oxidation basins.

Wastewater and runoff are collected at different points within the manufacturing area of the plant. The wastewater flows through four small basins for settling and skimming to the series of seven oxidation basins. Six of these basins contain mechanical aerators; one is unaerated. The discharge from the unaerated basin is pumped either to the last aerated basin or to a series of four large unlined facultative (facultative means both aerobic and anaerobic activity are present) basins. The wastewater effluent averages 11.7 million L/d and is discharged from either the last aerated basin or the last large facultative basin to surface water.

The discharge permit application for the plant included the information presented in Table F-16 about organic priority pollutants found at detectable levels in the effluent.

Preliminary sampling was performed on August 26, 1986, from the first facultative lagoon to determine the composition of wastewater in the lagoon and the potential for biodegradation and air emissions. The lagoon is 243,000 m^2 in area, and the depth ranges from 0.6 to 1.5 m. The lagoon was not well mixed.

Two samples, one near the bottom and one near the surface of the lagoon, were collected for chemical analysis. Each sample was pumped through tygon tubing into an amber glass bottle with Teflon-lined cap. The sampling point was 1.8 m from the north edge of the lagoon. In addition, samples were pumped into Nalgene containers from the same sampling point for biodegradation rate studies.

The chemical analysis for purgeable organics was done in accordance with EPA Method 624. The analysis involved a GC-MS search for 31 specific organic priority pollutants. None of these compounds was found in either sample above a minimum detection limit of 10 μg/L. The samples also were analyzed for acid, base, and neutral extractable compounds by EPA Method 625. The analysis involved a search for 81 specific organic compounds, none of which was found at concentrations above the minimum detection limit.

TABLE F-16. ORGANIC PRIORITY POLLUTANTS FOUND AT DETECTABLE LEVELS IN TSDF SITE 4 WASTEWATER EFFLUENT[a]

	Maximum 30-day value, μg/L	Long-term average value, μg/L
Methylene chloride	30	18
Acenaphthylene	10	10
Bis(2-ethyl hexyl) phthalate	71	24
Naphthalene	12	4

TSDF = Treatment, storage, and disposal facility.

[a]This table presents information obtained from the Site 4 discharge permit application.

Two experiments were performed to measure the oxygen consumption rate of the microorganisms in the wastewater. The first was the DO depletion experiment. A wide-mouth, amber glass, 0.5-L bottle was filled with wastewater from the biodegradation rate sample and allowed to come to thermal equilibrium. Air then was bubbled through the sample for approximately 5 min to raise the initial DO concentration. A magnetic stir bar was added to the sample bottle. The lid, fitted with a DO probe, was secured allowing the wastewater to overflow in order to ensure zero headspace within the bottle. The sample was stirred, and the DO concentration was recorded with time. Figure F-3 presents the results of the DO depletion experiment. In addition, on the basis of the measured oxygen uptake rate, the amount of biomass at this facultative lagoon was estimated to be 0.044 g/L.

The second oxygen uptake rate experiment performed was similar to a BOD determination. A 300-mL sample was added to a 0.5-L amber glass respirometry bottle. The respirometry bottle lid has a tube fitting that allows the bottle to be connected to a mercury manometer. A T-connector was inserted in the manometer tubing, lithium hydroxide was poured in the side tube to absorb carbon dioxide, and the side tube was sealed. The bottle then was clamped in a wrist-action shaker and sufficiently agitated to ensure that oxygen transfer was not rate limiting. The pressure drop resulting from aerobic biological activity was measured with the mercury manometer as a function of time. The results of the BOD oxygen consumption experiment are presented in Figure F-4.

The presence of anaerobic biological activity was determined by the ability of the wastewater sample to produce gas in the absence of oxygen. In the test procedure, nitrogen was bubbled through the liquid sample to purge any oxygen that may have been introduced during sample collection or transfer. The sample container was then sealed with a lid modified with a small tubing connection to a quantitative gas collection system. Two different gas collection systems were used. One system consisted of a water-filled inverted graduated cylinder that collected gas by water displacement. The second gas collection system consisted of a horizontal syringe whose free-moving plunger provided a quantitative measure of the volume of

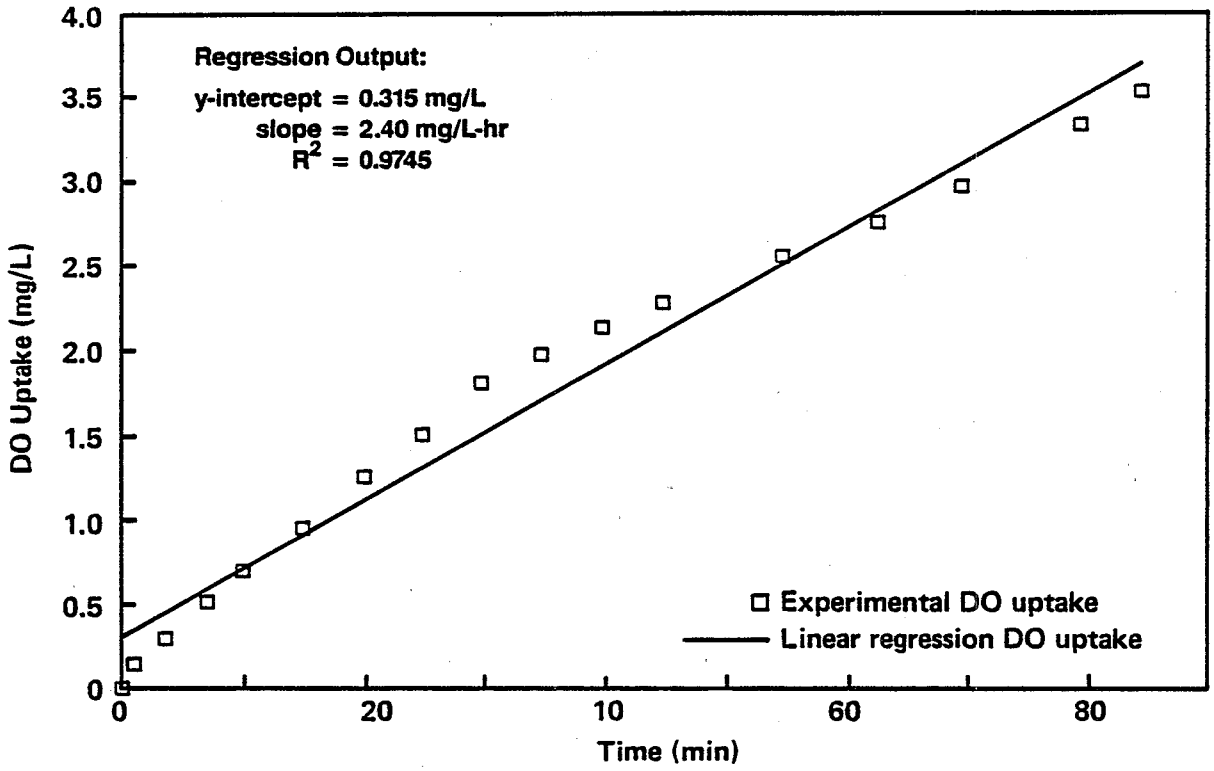

Figure F-3. TSDF Site 4 dissolved oxygen uptake curve.[9]

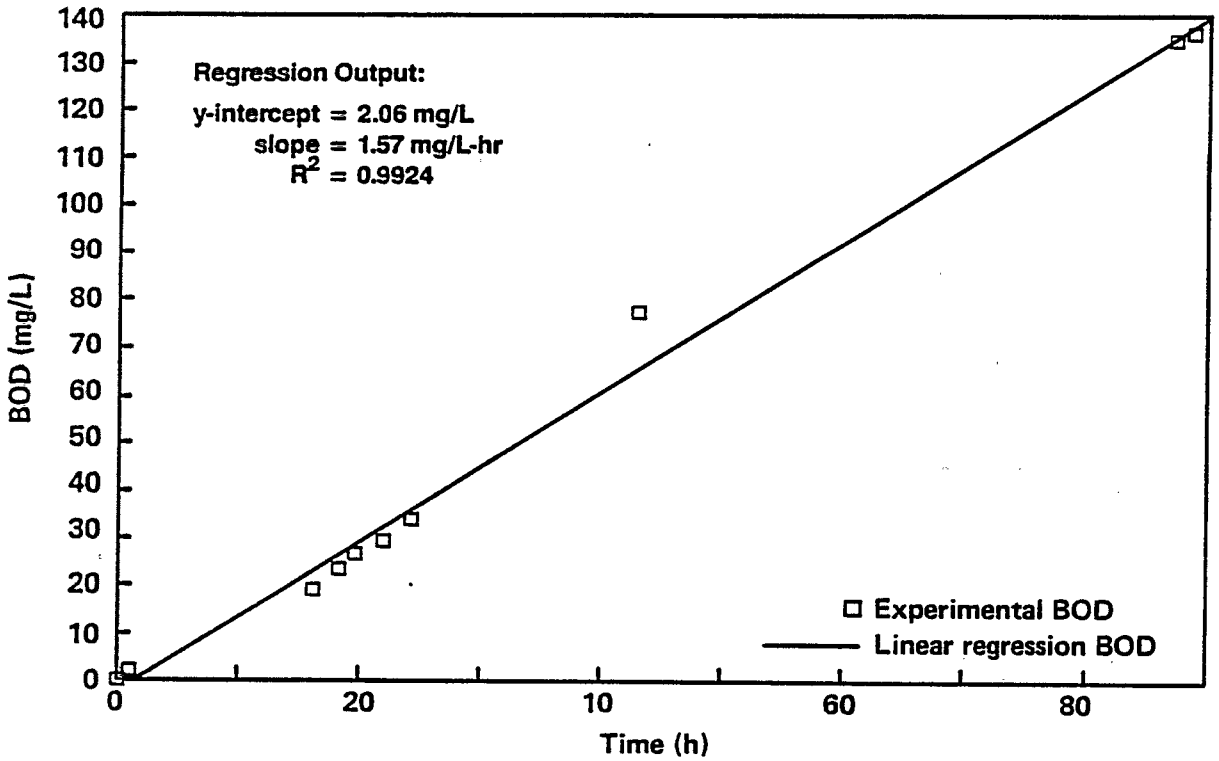

Figure F-4. TSDF Site 4 biochemical oxygen demand curve.[10]

gas produced. Direct exposure of the sample to light was limited by employing amber glass sample containers or cardboard box shields. Anaerobic gas generation in the sample from the first facultative lagoon at Site 4 was measured to be 0.022 mL/L-h.

F.1.1.5 Site 5.[11] Site 5 is a chemical manufacturing plant that produces primarily nitrated aromatics and aromatic amines. The raw materials for this process include benzene, toluene, and nitric and sulfuric acid. A field study program was conducted during a 3-day period from November 18 to November 20, 1985. The lagoon studied during the testing program was the wastewater holding pond for the WWT system at the plant. The WWT system includes two decant tanks, a steam stripper, a carbon adsorption system, and final pH-adjustment tank prior to the discharge of the wastewater stream into surface water.

The goals of the lagoon field study were to:

- Evaluate the three-dimensional variation of organic chemical concentrations in the Site 5 wastewater holding lagoon
- Measure lagoon air emissions using emission isolation flux chambers.

Additional testing was performed on the Site 5 steam stripper (refer to Section F.2.3.1.3) and carbon adsorption system (refer to Section F.2.2.2).

Two wastewater streams that enter the process at the beginning are distillation bottoms from aniline production (Resource Conservation and Recovery Act [RCRA] waste code K083) and the nitrobenzene production wastewater (RCRA waste code K104). These two wastewater streams flow into a holding tank, called the "red" tank, due to the color of the wastewater streams. As the tank is filled, the overflow passes through a submerged outlet into the wastewater holding lagoon. The third process stream that enters the lagoon is the plant sump wastewater. This stream is intermittent and occurs primarily during periods of heavy rain. Two sump pumps are activated when needed, both of which pump into the lagoon. The organic sump pump is normally the only one in operation and pumps directly into the steam-stripper feed tank.

The lagoon where the test program was conducted is 105 m by 36 m by 3 m (the depth is measured from the plant roadway elevation rather than

from the top of the berm). It is surrounded by a cement wall and a plant roadway on the east or plant side. The wall extends 0.3 m above the road surface. The berm on the other three sides is 1.7 m wide, consists of ground seashells, and extends to approximately the same height above the lagoon contents as the cement wall. The lagoon is lined with packed clay. During the test period, the liquid level in the lagoon ranged from 1.2 m to 2.1 m in depth, with about 40.6 cm of freeboard (measured down from the level of the plant roadway) above the liquid surface. The remaining depth was comprised of a bottom sludge layer, the thickness of which was never measured directly. By subtraction, this layer varied from about 0.6 m to 1.5 m deep. Retention time in the lagoon is 20.8 days.

Sampling locations were selected using a systematic approach. The lagoon was divided into 15 grids of equal area; each was approximately 12 m by 21 m or 250 m^2. Four of the grids (A, B, E, and F) were chosen for liquid and air emission sampling. Two liquid grab samples were collected from the impoundment surface at each sampling location just prior to placing the flux chamber in position. Duplicate gas canister samples were collected at each flux chamber location. An additional location near the southwest corner of the lagoon was sampled to examine the effect of a sludge layer on the emission processes. Sludge layer emissions were measured, and two liquid and one sludge sample also were collected. After the flux chamber samples were collected, liquid samples were collected at 0.3-m increments of depth, and a sediment sample was collected from the bottom at each of four of the sampling locations (A, B, E, and F) for the stratification study. Sampling spanned 2 days; Locations A and B were sampled on November 19, 1985, and Locations E and F and the southwest corner on November 20, 1985.

Gas samples were collected in evacuated stainless-steel canisters. Liquid grab samples from the impoundment surface were collected in clean, glass VOA vials fitted with Teflon capliners. A Bacon Bomb sampler, designed for collecting samples from storage tank bottoms, was used to collect liquid grab samples from specified depths for the stratification study. This sampler consists of a nickel-plated brass container with a protruding plunger. A cord was attached to the upper end of the plunger to

open the bomb, which closed when tension on the cord was released. A Ponar grab sampler (clamshell-type scoop) was used to sample sediment and sludge to a depth of several centimeters at the bottom of the lagoon. Offsite analyses of gas, liquid, and sludge samples were performed on a Varian Model 3700 GC with flame ionization detector/photoionization detector/Hall electrolytic conductivity detector (FID/PID/HECD).

Table F-17 presents the results of the direct emission measurement program. Results of the stratification analyses are summarized in Table F-18. The results for each grid point provide fairly conclusive evidence of stratification between the liquid and sludge layers, but not in the liquid layer itself. The sludge layer ranged up to several hundredfold more concentrated than the liquid layer. Table F-19 provides the results of a comparison of the liquid and sludge organic contents using an average concentration for each of the four primary lagoon organic components (nitrobenzene, 2,4-dinitrophenol, 4,6-dinitro-o-cresol, and benzene) reported in the liquid and sludge layers.

F.1.1.6 Site 6.[15] Site 6 is a commercial hazardous waste TSDF. The site began operation in 1972 and was acquired by the current owner in 1979 and upgraded to accept hazardous wastes. Before a waste is accepted for disposal at the facility, samples must be analyzed to determine compatibility with the facility processes. Water-reactive, explosive, radioactive, or pathogenic wastes are not accepted. Hazardous wastes are received from the petroleum, agricultural products, electronics, wood and paper, and chemical industries.

Emission measurements were performed for 2 days during the period from June 18 through 23, 1984, on a surface impoundment at Site 6. Source testing of inactive and active landfills at Site 6 is described in Section F.1.3.2. Section F.1.5.1 presents the results of the Site 6 drum storage and handling area testing.

The surface impoundment is used for volume reduction via solar evaporation. There is daily activity at most of the Site 6 surface impoundments. Wastes are transported to the impoundments by tank truck. During the first day of testing at the impoundment, a liquid-phase material balance was made over an 8.5-h period. According to company records, 58,000 L of waste were dumped into this impoundment during this 8.5-h period.

TABLE F-17. SOURCE TESTING RESULTS FOR TSDF SITE 5, WASTEWATER HOLDING LAGOON[12]

Constituent	Emission rate,[a] x 10^3 Mg/yr	Liquid concentration,[b] x 10^3 mg/L	Mass transfer coefficient,[c] x 10^6 m/s
Cyclohexane	1.8	38	0.4
Tetrachloroethylene	0.7	58	0.1
Toluene	2,800	2,600	9.0
Benzene	7,600	17,000	3.7
n-Undecane	3.7	150	0.2
Methylchloride	120	29	35
Total NMHC[d]	15,000	75,000	1.7

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.

[a]Average of emission rates measured with a flux chamber at Grid Points A, B, E, F, and the SW corner.

[b]Average of concentrations measured from liquid samples taken at Grid Points A, B, E, F, and the SW corner.

[c]Calculated from measured emission rates and liquid concentrations.

[d]The NMHC totals do not represent column sums because only constituents detected in gas and liquid samples are presented.

TABLE F-18. STRATIFICATION STUDY RESULTS[a] FOR TSDF SITE 5, WASTEWATER HOLDING LAGOON[13]

Sample location[b]	Sample type	Sample depth, m	Constituent concentration[c]			
			Nitro-benzene	2,4-Dinitro-phenol	4,6-Dinitro-o-cresol	Benzene
A-1	Liquid	0-0.3	440	1,400	32	12
B-1	Liquid	0-0.3	630	160	38	15
E-1	Liquid	0-0.3	390	130	25	17
F-1	Liquid	0-0.3	670	470	63	16
A-2	Liquid	0.9	560	250	28	13
B-2	Liquid	0.9	880	320	45	23
E-2	Liquid	0.9	420	<20	15	21
F-2	Liquid	0.9	460	3,000	82	30
A-3	Liquid	1.2	480	210	45	9.4
E-3	Liquid	1.2	380	260	<10	32
F-3	Liquid	1.2	350	110	30	59
A-4	Liquid	1.5	1,100	210	56	23,000[d]
A-5	Sludge	1.8	87,000	4,600	2,300	1,000
B-5	Sludge	1.2	130,000	18,000	7,700	1,000
E-5	Sludge	1.5	14,000	9,300	3,300	372
F-5	Sludge	1.5	120,000	5,200	2,600	2,400

TSDF = Treatment, storage, and disposal facility.

[a]This table presents the results of the analysis of three-dimensional variation of organic chemical concentrations in the TSDF Site 5 wastewater holding lagoon. Liquid samples were collected at 0.3-m increments of depth and a sediment sample was collected from the bottom at each of four sampling locations.

[b]Sampling grid (A, B, E, and F) and sample number at each depth within the grid (1, 2, 3, 4, and 5).

[c]Concentration results are gas chromatography-flame ionization detector analyses, in mg/L for liquids and mg/kg for sludges.

[d]Sample contaminated with sludge.

TABLE F-19. SLUDGE:LIQUID ORGANIC CONTENT COMPARISON FOR TSDF SITE 5, WASTEWATER HOLDING LAGOON[14]

	Liquid data	Sludge data	Weight ratio sludge:liquid
Estimated waste volume	4,400 m^3	4,100 m^3	
Average waste constituent concentrations[a]			
Nitrobenzene	560 mg/L	88,000 mg/kg	
2,4-Dinitrophenol	460 mg/L	9,300 mg/kg	
4,6-Dinitro-o-cresol	38 mg/L	4,000 mg/kg	
Benzene	22 mg/L	1,200 mg/kg	
Estimated weight of waste constituent			
Nitrobenzene	2,500 kg	360,000 kg	144
2,4-Dinitrophenol	2,000 kg	38,000 kg	19
4,6-Dinitro-o-cresol	170 kg	16,000 kg	94
Benzene	100 kg	4,900 kg	49
		Average =	77

TSDF = Treatment, storage, and disposal facility.

[a]Average concentrations calculated using all liquid values greater than detection limits.

The objectives of the testing program at the surface impoundment were:

- To obtain emission rate data using the emission isolation flux chamber approach
- To obtain emission rate data using a mass balance approach
- To obtain data on the concentration of VO for comparison to compounds identified during emission measurements and as future input to predictive models.

The surface impoundment is a rectangular pond with nominal dimensions of 137 m by 46 m. The entire surface of the pond was gridded (24 equal grids). Emission measurements using the flux chamber and liquid samples were collected on June 20 and June 22, 1984. Six sampling locations (grids) were randomly selected for the flux chamber measurements. However, only three different locations could be sampled (one sample per location) on the first day and four different locations (one sample each at two locations and duplicate samples at two locations) on the second day because of time constraints. Liquid samples were taken corresponding to each emission measurement at each sampling location.

Air emission measurements were made using the emission isolation flux chamber. It should be noted that during the flux chamber measurements, an additional 30.5 m of sampling line was required to reach the sampling locations from the shore. Under normal conditions, the flux chamber is operated with 3.1 m of sampling line. In addition, during collection of the canister samples on June 20 at two sampling locations, the chamber differential pressure was higher than normal. This abnormality may have affected those canister results on June 20.

Air samples were collected in evacuated stainless-steel canisters and analyzed offsite by a Varian Model 3700 GC-FID/PID/HECD. Liquid samples were collected in glass vials with Teflon-lined caps following the guidelines outlined in American Society of Testing and Materials (ASTM) D33701, "Standard Practices for Sampling Water."[16] Liquid samples also were analyzed offsite by the Varian Model 3700 GC-FID/PID/HECD. Table F-20 summarizes the test results for the Site 6 surface impoundment.

F.1.1.7 Site 7.[17,18] Site 7 is a commerical hazardous waste management facility located in the northeastern United States. The site was developed for hazardous waste operations in the early 1970s.

TABLE F-20. SOURCE TESTING RESULTS[a] FOR TSDF SITE 6, SURFACE IMPOUNDMENT

Constituent	Mean emission rate, Mg/yr	Mean liquid concentration, mg/L	Mass transfer coefficient,[b] $x10^6$ m/s
June 20, 1984, results[c]			
Toluene	0.4	9.0	0.2
Ethylbenzene	0.2	4.9	0.2
Methylene chloride	2.4	18	0.7
1,1,1-Trichloroethane	4.9	28	1.2
Chloroform	0.2	1.0	0.9
p-Dichlorobenzene	0.1	1.8	0.3
Total NMHC[d]	16	320	0.2
June 22, 1984, results			
Toluene	2.0	4.3	2.4
Ethylbenzene	1.1	5.4	1.0
Methylene chloride	6.8	4.2	8.4
1,1,1-Trichloroethane	9.3	19	2.6
Chloroform	0.5	0.2	12
p-Dichlorobenzene	0.1	2.0	0.4
Total NMHC[d]	61	280	1.1

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber and liquid concentrations were determined from grab samples.

[b]Calculated from measured emission rates and liquid concentrations.

[c]During collection of the canister samples on June 20 at two sampling points, the chamber differential pressure was higher than normal. This abnormality may have affected those canister results on June 20.

[d]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

The site's aqueous WWT system has a throughput of 545,000 L/d with typical discharges ranging from 330,000 to 382,000 L/d. At the time of the tests, wastes accepted into the WWT system included washwaters, pickle liquors, and leachates from other facilities within the WWT system. The WWT process at Site 7 includes chemical, physical, and biological treatment. A holding pond, a reducing lagoon, and an oxidizing lagoon of the WWT system were tested for emissions during the first week of October 1983. Testing of an active and a closed landfill at Site 7 is described in Section F.1.3.5. Section F.1.5.3 discusses testing of emissions from the Site 7 drum storage building.

The holding pond is an 18,000-m^3 aerated (pump aerator) Hypalon-lined lagoon that receives the aqueous phase from the salts area of the WWT system. The aqueous phase includes organics that are soluble or suspendible at a pH greater than 11.5. Dimensions of the pond are nominally 135 by 36 by 3.1 m. Freeboard ranges from 0.6 to 1.5 m. Filling and discharge of the holding pond are conducted monthly. The field test took place several days after draining. At the time of the test, the pond had a nominal 0.3 to 0.5 m of liquid waste and several meters of sludge present. Because of the low liquid level, the pump aerator was not operational.

The reducing lagoon is a 3,900-m^3 Hypalon-lined lagoon that receives incoming wastes to the WWT system that are classified as reducing agents. The pH is typically less than 2. Dimensions of the lagoon are nominally 34 by 33 by 3.9 m. The freeboard ranges from 0.6 to 1.5 m. Liquid waste is received via tank truck and discharged through a flexible hose into the lagoon. Localized discharges into the corners of the lagoon have created a zone of bulk solids, precipitation products, and construction debris. The surface of the lagoon was coated with an oil film. The frequency of waste unloading observed during the field test was nominally four to five tank trucks per day. The frequency is not regular. The WWT system is operated on a batch basis, making the residence time (throughput) dependent upon the volume of waste received into the system.

The oxidizing lagoon is a 3,900-m^3 Hypalon-lined lagoon that receives incoming wastes to the WWT system that are oxidizing agents. The wastes include halogens and organics compounds (total organic carbon less than

2 percent) and have a pH less than 2. Dimensions of the lagoon are nominally 35 by 35 by 4.1 m. The freeboard ranges from 0.6 to 1.5 m. Liquid waste is received via tank truck and discharged through flexible hose into the lagoon. Localized discharges into the north corner of the lagoon have created a prominent "delta" of bulk solids, precipitation products, and construction debris. The surface of the lagoon was coated with an oil film. The frequency of waste unloading observed during the field test appeared somewhat greater for the oxidizing lagoon than for the reducing lagoon (four to five truckloads per day). As with the reducing lagoon, the oxidizing lagoon is a batch operation, making the residence time (throughput) dependent on the volume of waste received.

The objective of the testing program at Site 7 surface impoundments was to develop and verify techniques for estimating air emissions from these sources. The reducing lagoon and oxidizing lagoon were each gridded, and air emission measurements were made within certain grids using the flux chamber technique. Liquid samples were obtained concurrent with flux chamber testing. Concurrent samples were collected from two grids at each lagoon. Duplicate flux chamber measurements and concurrent liquid samples were taken at a single location in the holding pond.

Air sample collection was made by evacuated stainless-steel canisters, and analysis was conducted offsite using a Varian Model 3700 GC-FID/PID/HECD. Liquid samples were collected in glass containers in a manner that would minimize any headspace and analyzed offsite by the Varian Model 3700 GC-FID/PID/HECD. Tables F-21 through F-23 summarize the test results from the holding pond, reducing lagoon, and oxidizing lagoon, respectively.

F.1.2 Wastewater Treatment

F.1.2.1 Site 8.[19,20]

Site 8 is a petroleum refinery located on the East Coast with a capacity of 180,000 barrels per day. Limited quantities of benzene, toluene, and cumene are also produced. Most of the operations are continuous (as opposed to batch) processes. Rainwater collected in the process area is treated as process wastewater.

The plant has two separate primary treatment trains that treat wastewater from different process areas. The more concentrated wastewater

TABLE F-21. SOURCE TESTING RESULTS[a] FOR TSDF SITE 7, HOLDING POND

Constituent	Mean emission rate, x 10^6 Mg/yr	Mean liquid concentration, x 10^3 mg/L	Mass transfer coefficient,[b] x 10^9 m/s
Benzene	7,900	19	2,700
Toluene	81,000	230	2,300
Ethylbenzene	15,000	37	2,600
Naphthalene	500	2	1,600
Methylene chloride	240,000	500	3,100
Chloroform	3,400	10	2,200
1,1,1-Trichloroethane	18,000	30	3,900
Chlorobenzene	<370	62	<39
p-Dichlorobenzene	6,000	9	4,300
Acetaldehyde	11,000	21	3,400
Total NMHC[c]	1,200,000	2,600	3,000

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber and liquid concentrations were determined from grab samples.

[b]Calculated from measured emission rates and liquid concentrations.

[c]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

TABLE F-22. SOURCE TESTING RESULTS[a] FOR TSDF SITE 7, REDUCING LAGOON

Constituent	Mean emission rate, x 10^6 Mg/yr	Mean liquid concentration, x 10^3 mg/L	Mass transfer coefficient,[b] x 10^6 m/s
Benzene	1,600	9.2	4.9
Toluene	160,000	910	5.0
Ethylbenzene	2,700	14	5.5
Styrene	2,000	10	5.7
Naphthalene	500	5.4	2.6
Methylene chloride	12,000	29	12
Chloroform	1,000	5.0	5.7
1,1,1-Trichloroethane	35,000	130	7.6
Carbon tetrachloride	12,000	31	11
p-Dichlorobenzene	38,000	420	2.6
Total NMHC[c]	640,000	3,600	5.0

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber and liquid concentrations were determined from grab samples.

[b]Calculated from measured emission rates and liquid concentration.

[c]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

TABLE F-23. SOURCE TESTING RESULTS[a] FOR TSDF SITE 7, OXIDIZING LAGOON

Constituent	Mean emission rate, x 10^3 Mg/yr	Waste concentration,[b] μg/g	Mass transfer coefficient,[c] x 10^9 m/s
Toluene	170	7.8	380
Ethylbenzene	43	20	37
1,1,1-Trichloroethane	2,000	1.0	35,000
Total NMHC[d]	7,600	1,400	94

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.

[a]This table presents the results of analyses of air and waste oil and solids mixture samples collected during source testing at the TSDF Site 7 oxidizing lagoon. Air emissions were sampled with a flux chamber and waste concentrations were determined from grab samples.

[b]The lagoon surface contained oils and solids; therefore, the grab sample of waste from the pond was a sludge and was analyzed as a soil sample.

[c]Calculated from measured emission rates and waste concentration.

[d]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

stream (containing most of the petrochemical plant wastewater and some of the refinery wastewater), typically 5,700 to 7,600 L/min, flows to a skim and surge tank that is operated for hydraulic equalization (i.e., the tank level rises and falls while wastewater is pumped out at a relatively constant rate). The water flows to an API separator. Effluent from this separator is mixed with a small volume of "desalter water" and then passes through two parallel roughing filters. The roughing filter effluent is combined and then divided between two parallel 18 m diameter by 2.4 m deep primary clarifiers. The underflow from the primary clarifiers is pumped to two thickeners. The primary clarifier overflow is combined and split between the two parallel 37 m diameter by 5.5 m deep oxidation tanks. These tanks have approximately 0.6 m of freeboard and hold 5.7 million L each.

The second wastewater stream enters a skim and surge tank that is operated for hydraulic equalization and is gravity fed at a relatively constant rate (typically 9,500 to 11,000 L/min) to a second API separator. The effluent from the separator is evenly split between the two oxidation tanks. This wastewater enters the oxidation tanks as a separate stream from the other treatment train.

Air is supplied to the oxidation tank from one of three available 600 horsepower compressers. The air is approximately evenly divided between the two tanks and enters through a distributor system of 2,000 diffusers per tank. The dissolved oxygen in the tanks is typically maintained between 1.5 and 2.0 mg/L. The oxidation tanks are typically operated at 1,800 to 2,300 mg/L of mixed liquor volatile suspended solids. Based on a combined wastewater flow of 19,000 L/min, the residence time in the oxidation tanks is approximately 10 to 11 hours.

The overflow from the two aeration tanks is combined and then split between two parallel secondary clarifiers. The clarifiers are 43 m in diameter and 2.7 m deep. The overflow from the clarifiers is combined and passed through a final sand filter before discharge to the river. About 1/3 of the flow to the secondary clarifiers is pumped from the bottom and returned to the aeration tanks. These streams are not combined (the east secondary clarifier returns sludge to the east oxidation tank; the west

secondary clarifier returns sludge to the west oxidation tank). When necessary to limit the mixed liquor suspended solids (MLSS) to the desired range of 1,800 to 2,300 mg/L, sludge is wasted from the return lines. The oxidation tank in the east was 2,300 mg/L during the test, based on analyses conducted by the plant. No sludge was being wasted at the time of the site visit. Waste-activated sludge is pumped to the thickeners where it is combined with primary sludge. The thickened sludge is centrifuged and the solids are incinerated.

A field test to measure air emissions from one of the two parallel oxidation tanks (using a mass emissions flux chamber) and biodegradation rates was conducted in August 1987. For flux chamber sampling, the oxidation tank was divided into five concentric rings, each having an equal area. Emissions were first measured along a diameter at the midpoint of each ring. In addition to these 10 points, the tank's centroid and three other points were also sampled. The three additional points lay on two transverse lines 25° and 43° off the original transect line.

Air samples were taken in evacuated canisters and analyzed by GC-FID/PID/HECD. Using sample concentrations and airflow rates as measured with the flux chamber, average emissions were calculated for the tank surface. The emissions data are tabulated by compound in Table F-24. Note that these emissions are given for a single aeration tank and should be doubled to approximate the total emissions from the activated sludge units at the refinery.

Biodegradation rate tests were conducted with mixtures of aeration tank influent and recycled sludge. The more concentrated of the two aeration tank influent streams was used. This resulted in higher, and thus easier to detect, concentrations of benzene, toluene, and xylene than the average concentration of the combined tank influents.

In order to distinguish between removal of organics from mixed liquor due to biodegradation and removal due to mass transfer into the air, experiments were conducted that permitted biodegradation to take place while limiting air stripping. The samples of aeration tank feed and recycled sludge were mixed in proportions that reflected the actual ratio of aeration tank feed and recycle sludge at the time they were taken.

TABLE F-24. SOURCE TESTING RESULTS[a] FOR TSDF SITE 8, AERATION TANK

Compound	Emission rate, x 10^3 Mg/yr	Liquid concentration, μg/L	Mass transfer coefficient,[b] x 10^6 m/s
Methane	510	NA	NC
C-3 VOC	17	NA	NC
n-Heptane	28	NA	NC
n-Octane	53	NA	NC
n-Nonane	68	NA	NC
n-Decane	57	NA	NC
n-Undecane	34	NA	NC
3-Methylheptane	23	NA	NC
Methyl-cyclohexane	19	NA	NC
Toluene	26	<2.7	>280
Cyclopentane	1.2	NA	NC
Isoheptane	11	NA	NC
Benzene	1.7	<1.1	>47
p,m-Xylene	5.1	<1.1	>140
o-Xylene	3.9	<1.1	>100
Ethylbenzene	1.4	NA	NC
TNMHC[c]	1,200	NA	NC

NA = Not analyzed.
NC = Not calculated.
TNMHC = Total nonmethane hydrocarbons.

[a]Air emission data estimated from flux measurements made at different points on the surface of a submerged aeration activated sludge tank. Liquid composition estimated from average of eight samples of aeration tank effluent taken over an 8-day period. Note that the test was conducted on, and data were reported for, one of two identical aeration tanks at the refinery.

[b]Calculated from measured emission rates and average effluent concentration. Tank area = 1,080 m^2.

[c]The TNMHC emission rate is based on a chromatographic trace that includes unidentified hydrocarbons not listed in this table.

The gross sample was divided using a 2-L Nalgene^R graduated cylinder as follows: seven 1-L bottles were partially filled with 500 cm^3 of mixture, and two 500-cm^3 bottles were completely filled with mixture. The filled bottles were designated for volatile suspended solids analysis and immediately stored on ice. One of the partially filled 1-L bottles was immediately preserved with 10 mL of saturated copper sulfate solution and agitated gently to ensure that the copper sulfate solution was distributed. Approximately 100 mL was then poured from the bottle into a disposable polypropylene beaker. The beaker was then used to fill two pre-acidified 40-cm^3 septum vials. The two 40-cm^3 bottles were stored on ice immediately thereafter.

The partially filled 1-L bottles and the partially filled 500-mL bottle were then mounted on a wrist action shaker and continuously agitated. As time progressed, bottles were removed from the shaker, one by one, and preserved with copper sulfate using the same procedure as for the initial sample. The test was conducted over a period of approximately two oxidation tank residence times. Similarly, 40-cm^3 vials of acidified sample were filled for purgeable organics analysis. The temperature of the test mixture at T=0 was 35 °C. The ambient temperature where the test was conducted varied between 23 and 27 °C. Biodegradation rate test samples were analyzed for benzene, toluene, and xylenes by EPA Method 602. A total of three tests were conducted, one each on August 4, 5, and 6, 1987.

An attempt was made to simultaneously measure total oxygen uptake of the mixture by a respirometric technique. This proved unsuccessful, possibly because of interferences from dissolved gases in the mixture. The test was, however, conducted under conditions in which an excess of oxygen was always available.

Upon analysis of the preserved samples, it was found that essentially all of the benzene, toluene, and xylene present in the mixture was biodegraded between the T=0 sample and the next sample (taken at approximately 2 hours). Thus, only lower bounds on biodegradation rates could be calculated. Rates determined for the three tests are presented in Table F-25.

Because of the higher than expected removal rates, lower bounds on compound-specific zero order biodegradation rates were based on the removal

TABLE F-25. BIODEGRADATION RATES[a] DETERMINED BY SHAKER TESTS AT SITE 8

Compound	Biodegradation rates, μg/min-gbiomass		
	Test 1	Test 2	Test 3
Benzene	>3.5	>1.4	>0.40
Toluene	>4.3	>1.8	>0.58
p-Xylene	>0.60	>0.15	>0.17
m-Xylene	>1.7	>0.84	>0.47
o-Xylene	>1.3	>0.46	>0.34
Total xylenes	>3.5	>1.44	>0.94

[a]These rates reflect the essentially complete disappearance of the compounds present at the beginning of the test over a reaction time of 110 to 120 minutes. The rates have been normalized by the biomass concentration as determined from a parallel analysis. The difference in rates between tests is caused by changes in the composition of the aeration tank influent on successive days.

rate observed in the first reaction time interval normalized by the independently determined volatile suspended solids concentration:

$$K = \frac{C_o - C_t}{t\ B}$$

where:

K = lower bound on biodegradation rate, μg compound/(min-gbiomass)
C_o = concentration of compound in bottle preserved at t = 0, μg/L
C_t = concentration of compound in bottle preserved next, μg/L
t = reaction time, minutes
B = volatile suspended solids concentration in bottles, g/L.

For two of the three tests, C_t was below detection level for all of the compounds of interest. The lack of intermediate data precludes the calculation of first order rate constants or constants of the more complicated Monod kinetic models.

F.1.2.2 Site 9.[21] Site 9 is a synthetic organic chemical production plant. Plant wastewater is treated in a system that includes two parallel, mechanically aerated, activated sludge units that discharge to a UNOX-activated sludge system. A field test was conducted in November 1986 to determine biodegradation rates for methanol and formaldehyde. Biodegradation rates were determined for the mechanically aerated systems by testing a sample composed of aeration tank feed and recycled sludge mixed in proportions to actual unit flows.

Each sample was divided using a 2-L plastic graduated cylinder as follows: up to seven 1-L bottles were partially filled with 500 mL of mixture, one 1-L bottle was completely filled with the mixture, and one specially prepared 500-mL bottle was partially filled with 250 mL of the mixture. The filled bottle was designated for volatile suspended solids analysis and immediately stored on ice. One of the partially filled 1-L bottles was immediately preserved with 10 mL of saturated copper sulfate solution and agitated gently to ensure that the copper sulfate solution was distributed. This bottle was then used to fill two 40-mL septum vials.

The 1-L bottle and the two 40-mL bottles were stored on ice immediately thereafter for shipment to a laboratory for organic compound analysis.

The specially prepared 500-mL bottle had a plastic tubing stub fitted into and protruding through the cap. Polyvinyl chloride (PVC) tubing was connected to the stub leading to a plastic T-connector. One side of the T-connector was attached to a short length of tubing filled with lithium hydroxide. The other side of the T-connector was connected to a mercury manometer. This bottle was used to monitor oxygen uptake over time.

The partially filled 1-L bottle and the partially filled 500-mL bottle were then mounted on a wrist-action shaker and continuously agitated. Over a period of up to 24 h, bottles were removed from the shaker one by one and preserved with copper sulfate using the same procedure as for the initial sample. Similarly, 40-mL vials were filled for purgeable organics analysis.

Biodegradation rate test samples were analyzed for purgeable organics by EPA Method 624 (formaldehyde by an MS technique,[22] and methanol by direct-injection GC).

Based on the decrease in methanol and formaldehyde with increasing reaction times, zero-order biodegradation rates were calculated. These rates were then normalized by dividing by the biomass present (as indicated by volatile suspended solids) in the bottles. Biodegradation rates for methanol and formaldehyde were determined to be 0.53 and 0.082 μg/(g•biomass-h), respectively.

F.1.2.3 Site 10.[23,24] Site 10 is a synthetic organic chemical production plant. Wastewater is collected at various points in the manufacturing area of the plant and pumped intermittently to a sump in the WWT area. Wastewater is pumped intermittently from this sump to an equalization tank with a residence time of approximately 90 h. The equalization tank is not completely mixed and is operated primarily to accommodate hydraulic surges.

Wastewater is then pumped to a splitter box where it is mixed with recycled sludge and divided between two identical and parallel, above-ground, concrete aeration tanks providing approximately 6 days of residence time. Air is supplied through static mixers in each tank. Approximately

5 cm of foam was present on the surface of the tanks except in the areas directly above the mixers. The aeration tanks contained 2,500 mg/L of mixed-liquor suspended solids during the test. The water level is maintained by an overflow weir.

The wastewater from the two tanks overflows to a splitter box where it is recombined and then divided evenly between two clarifiers. Sludge is returned to the aeration tanks at the influent splitter box in an amount sufficient to maintain the desired volatile suspended solids content of the mixed liquor.

One tank was divided into 27 2.44 m x 2.44 m grids. An enclosure device, the isolation emission flux chamber, was used to measure the off-gas flow rate from the different parts of a grid. A slipstream of the sample gas was collected for hydrocarbon analysis.

A field test to measure air emissions (with a mass emissions flux chamber) and biodegradation rates was conducted in September 1986. Compound-specific air emissions integrated over the tank surface are given in Table F-26 along with liquid concentration data obtained from analyses of mixed-liquor samples taken at the same points at which the flux chamber measurements were made. Gas and liquid analyses were conducted by GC-FID/PID/HECD.

Samples of a mixture of aeration tank feed and recycled sludge were dipped from the influent splitter box at the upstream end of the aeration tank. Each sample was divided using a 2-L plastic graduated cylinder as follows. Up to seven 1-L bottles were partially filled with 500 mL of mixture; one 1-L bottle was completely filled with mixture; and one specially prepared 500-mL bottle was partially filled with 250 mL of mixture. The filled bottle was designated for volatile suspended solids analysis and immediately stored on ice. One of the partially filled 1-L bottles was immediately preserved with 10 mL of saturated copper sulfate solution and agitated gently to ensure that the copper sulfate solution was distributed. This bottle was then used to fill two 40-mL septum vials. The 1-L bottle and the two 40-mL bottles were stored on ice immediately thereafter for shipment to a laboratory for organic compound analysis.

TABLE F-26. AIR EMISSIONS AND MIXED-LIQUID COMPOSITION IN THE AERATION TANK AT SITE 10[a]

Constituent	Emission rate, x 10^3 Mg/yr	Liquid concentration, μg/L	Mass transfer coefficient,[b] x 10^6 m/s
Methane	170	0.0	NM
C-2 VOC[c]	1.1	15.8	6.9
Cyclopentane	.93	0.5	180
Isobutene + 1-Butene	.12	0.0	NM
t-4-Methyl-2-pentene	.11	0.0	NM
Toluene	2.9	1.6	180
Methylene chloride	.13	8.3	1.6
1,1,1-Trichloroethane	.70	6.0	12
Acetaldehyde	5.6	170	3.3
Dimethylsulfide	.13	4.9	2.6
Acetone	0[d]	70	0

NM = Not meaningful.
VOC = Volatile organic compound.

[a]Air emission data estimated from flux measurements made at different points on the surface of a submerged aeration activated sludge tank and the average composition of the mixed liquor present in the tank.

[b]Calculated from measured emission rates and liquid concentration.

[c]Volatile organic compounds containing two carbons, e.g., ethane.

[d]Acetone measurements from the tank surface did not exceed blank concentration levels.

The specially prepared 500-mL bottle had a plastic tubing stub fitted into and protruding through the cap. Tygon tubing was connected to the stub leading to a plastic T-connector. One side of the T-connector was attached to a short length of tubing filled with lithium hydroxide. The other side of the T-connector was connected to a mercury manometer. This bottle was used to monitor oxygen uptake over time.

The partially filled 1-L bottle and the partially filled 500-mL bottle were then mounted on a wrist-action shaker and continuously agitated. Over a period of about 19 h, bottles were removed from the shaker one by one and preserved with copper sulfate using the same procedure as for the initial sample. Similarly, 40-mL vials were filled for purgeable organics analysis.

Biodegradation rate test samples were analyzed for purgeable organics by EPA Method 624, acid extractable organics by EPA Method 625, and methanol by direct injection GC.

The slope of the linear regression line through the data points represents the best estimate of the compound-specific biodegradation rate. Concentrations would be expected to decline monotonically in the absence of chemical analysis errors. This slope was then normalized for the biomass concentration. Selected biodegradation rate constants are given in Table F-27. Multiple rates for the same compound reflect data obtained during different tests. Taking the rate constant for phenol, as an example, as 0.25 μg/min-g biomass, would imply that a tank with mixed-liquor volatile suspended solids of 2,500 mg/L could effectively biodegrade 5,400 μg/L of phenol. The actual difference between phenol in the influent and the effluent of the aeration tank during the study period averaged 6,200 μg/L (based on a weighted average of aeration tank feed concentration and recycled sludge vs. aeration tank effluent); the effluent and recycle streams were below the detection limit of 250 μg/L.

F.1.2.4 Site 11.[25] The Site 11 facility produces acrylic fibers by the continuous polymerization of acrylonitrile with methyl methacrylate. Wastewater from this process is discharged to an aerated equalization basin and then treated by flocculation before being disposed of by deep-well injection. Tests were conducted on the discharge trough and equalization basin on May 20 and 21, 1986.

TABLE F-27. BIODEGRADATION RATE CONSTANTS OBSERVED IN SHAKER TESTS CONDUCTED AT SITE 10 AERATION TANK[a]

Constituent	Rate constant, μg/(min-g biomass)
Methanol	12.8 5.7
Phenol	0.087 0.25 0.29
2,4,6-Trichlorophenol	0.037
Styrene	0.0011
Oxirane	0.38 0.59
1,1,1-Trichloroethane	0

TSDF = Treatment, storage, and disposal facility.

[a]This table presents zero-order biodegradation rate constants determined from analyses of shaker test samples at Site 10. Where more than one rate is presented, data were obtained from different tests conducted during a 1-week period.

The process wastewater containing acrylonitrile is discharged into an open trough where it cascades downhill the length of the freeboard into the equalization basin. The trough is constructed of stainless steel and is approximately 30 cm wide with a total length of 8.2 m. The surface area of the basin is approximately 4,000 m^2. During the testing program, the trough length above the equalization basin waterline was approximately 6.4 m; the depth of the equalization basin was approximately 2.7 m. The estimated daily loading rate for acrylonitrile entering the equalization basin over the 2 days of the testing program was 115 kg/d, based on a mean discharge concentration of 56.8 ppm at 2 million L/d.

The objectives of the testing program at Site 11 were to determine:

- Acrylonitrile emissions from the discharge trough prior to the equalization basin
- Biological activity of the equalization basin
- Concentration of acrylonitrile in the equalization basin with respect to time.

To determine acrylonitrile emissions from the discharge trough, grab samples were collected at the trough influent and effluent. A beaker was dipped into the flow, and each sample was transferred into triplicate VOA vials. Samples were collected three times daily at approximately 4-h intervals. Initial readings for temperature and pH were recorded, and duplicate analyses using GC-FID were performed to determine the acrylonitrile concentration of each sample. Flow rate measurements were not performed because of the short period of time (less than 2 s) that the discharged wastewater resided in the trough. In addition, the flow rate in the discharge trough was highly variable, which led to alteration of the sampling protocol for the final four sampling events to allow for simultaneous collection of influent and effluent samples. Because of the short residence time in the trough and the change in sampling protocol, results of testing acrylonitrile emissions from the discharge trough prior to the equalization basin were inconclusive.

To quantify the biological activity of the equalization basin, BOD analyses were conducted on a representative sample of the basin. The sample was collected by compositing grab samples from four different points

about the perimeter of the basin with a glass container. Two separate BOD analyses were then prepared and run in triplicate. Dilutions of 0.5, 0.67, 1.33, and 1.67 percent were used, and the aliquots were left unseeded. Because BOD analyses also can measure the oxygen depletion used to oxidize reduced forms of nitrogen (nitrogenous demand), an inhibitor (2-chloro-6 [trichloromethyl]pyridine) was added to one set in order to better quantify the carbonaceous oxygen demand (COD) of the system. All analyses were performed in accordance with Standard Methods for the Examination of Water and Wastewater (16th Edition).[26] Table F-28 summarizes the results of the BOD analyses and shows essentially no change in mean BOD with addition of the inhibitor. This indicates that the oxygen demand on the system is not due to the oxidation of nitrogenous compounds and implies that oxygen demand is related to the biochemical degradation of organic material and the oxidation of inorganic materials such as sulfides.

To determine the acrylonitrile concentration in the equalization basin with respect to time, a total of three different composite grab samples was collected as described previously for the BOD analyses. After each collection, portions of the composite sample were allocated to eight VOA vials. Two of these were analyzed immediately to determine the initial acrylonitrile concentration of the basin. Three of the VOA vials then were set aside under ambient conditions to be analyzed after their respective holding time had elapsed. The remaining three were spiked with 5 μL of stock acrylonitrile and were analyzed to determine their initial acrylonitrile concentration; then they were set aside under ambient conditions to be reanalyzed after their respective holding time had elapsed. All of the acrylonitrile concentration determinations were conducted using a Hewlett-Packard 5840 GC-FID. The acrylonitrile concentrations of the basin composites were below the detection limit of 5 ppm. Table F-29 presents the acrylonitrile concentrations of the equalization basin spiked samples.

In addition to the eight VOA vials, three aliquots of each composite were placed in standard BOD bottles. The DO concentration then was measured with a YSI 5720A BOD DO probe. The ground-glass stoppers then were placed in the bottles, and a water seal was placed around the rim. The bottles were set aside under ambient conditions and were reanalyzed for DO

TABLE F-28. BIOCHEMICAL OXYGEN DEMAND RESULTS[a] FROM EQUALIZATION BASIN AT TSDF SITE 11[27]

Sample date	Time sampled	Percent of aliquot analyzed	Initial DO, ppm	Final DO, ppm	Mean BOD,[b] ppm	Analysis comments
5/20/86	1000	0.5	8.2	4.5	675	Total BOD
5/20/86	1000	0.67	8.2	4.0		
5/20/86	1000	0.5	8.2	4.6	685	Inhibited BOD
5/20/86	1000	0.67	8.2	4.0		
Method blank		NA	8.2	8.0		300 mL of dilution water
Method blank		NA	8.2	8.0		

TSDF = Treatment, storage, and disposal facility.
DO = Dissolved oxygen.
BOD = Biological oxygen demand.
NA = Not applicable.

[a]Grab samples from four different points about the perimeter of the basin were composited and two separate BOD analyses were prepared and run in triplicate. An inhibitor (2-chloro-6[trichloromethyl]- pyridine) was added to one set in order to better quantify the chemical oxygen demand of the system.

[b]BOD is calculated as follows: BOD = [(Initial DO - Final DO)/Aliquot %] x 100.

TABLE F-29. ACRYLONITRILE CONCENTRATIONS OF THE EQUALIZATION BASIN SPIKED SAMPLES[a] AT TSDF SITE 11[28]

Sample date	pH	Mean initial concentration, mg/L	Mean final concentration, mg/L	Percent reduction	Mean total holding time, h
5/20/86	7.0	93	52	44	34.4
5/20/86	6.7	97	45	54	28.5
5/21/86	3.2	99	105	NA	6.8

TSDF = Treatment, storage, and disposal facility.
NA = Not applicable.

[a]Grab samples from four different points about the perimeter of the basin were composited a total of three different times. After each collection, portions of the composite sample were allocated to eight volatile organic analysis vials, three of which were spiked with 5 μL of stock acrylonitrile. This table presents the results of the analyses of the three sets of spiked samples.

when their respective holding time had elapsed. Table F-30 presents the results of the DO analyses.

F.1.2.5 Site 12.[30] The Site 12 plant produces specialty chemicals in a number of separate batch operations. Wastewater originates from water used during the reaction process, water produced by the reaction, water used in rinsing the final products, and water used in cleaning operations. The wastewater is treated in a series of processes (neutralization, primary clarification, and activated sludge) prior to being discharged. Testing was conducted during the week of August 13 through 19, 1984.

The site was chosen because of the emission control system used to minimize odor from the aerated lagoon that is part of the activated sludge system. Therefore, the test program was focused on the lagoon enclosure. Specifically, the primary objectives of the lagoon enclosure testing were to:

- Measure the control efficiency of the activated carbon beds that were used in the treatment of the off-gases from the lagoon
- Measure the overall effectiveness of the dome and carbon adsorption systems
- Determine the validity of Thibodeaux's model for predicting emission rates from aerated impoundments.

In addition, the effectiveness of 0.21-m^3 drums of carbon used to control breathing and working losses from the neutralizer tanks was evaluated.

Results of the analysis of the effectiveness of the dome are presented in Section F.2.1.1. Effectiveness of the vapor-phase carbon adsorption is discussed in Section F.2.2.1.2.

The aerated lagoon at Site 12 is approximately 46 by 130 m. The lagoon aeration is performed by two large 56-kW (75-hp) aerators and 25 smaller 5.6-kW (7.5-hp) aerators. At least one of the large aerators and an average of 16 of the smaller aerators are operated at all times. The depth of the lagoon is generally held near 1.5 m. During the test period, the level was substantially lower at 0.55 m. The lagoon is covered with a PVC-coated polyester dome structure. The dome is an air-tight inflated bubble structure, approximately 9 m tall at the highest point. The dome is

TABLE F-30. DISSOLVED OXYGEN DATA FOR EQUALIZATION BASIN SAMPLES[a] AT TSDF SITE 11[29]

Sample date	pH	Mean initial DO, mg/L	Mean final DO, mg/L	Mean percent reduction	Mean total holding time, h
5/20/86	7.0	6.8	0.3	96	29.5
5/20/86	6.7	6.3	0.2	97	25.6
5/21/86	3.2	8.4	6.8	19	9.4

TSDF = Treatment, storage, and disposal facility.
DO = Dissolved oxygen.

[a]Grab samples from four different points about the perimeter of the basin were composited a total of three different times. After each collection, three aliquots of the composited sample were placed in standard biochemical oxygen demand bottles for DO concentration analysis.

pressurized by a main blower and equipped with an emergency fan, a propane-powered auxiliary blower (for use during power failures), and a propane heater (for winter operation). The air in the dome structure is purged continuously through a fixed two-bed carbon adsorption system. The beds are alternately regenerated every 24 h. The carbon adsorption system is designed to remove odorous compounds (primarily orthochlorophenol, which is not a VO) from the exhaust gases.

The wastewater from the batch reactors flows into two neutralizer tanks for pH adjustment. At the time of the tests, the plant estimated that the wastewater flow rate averaged 20.8 L/s. The capacity of each tank is approximately 75,000 L. In the neutralizer tanks, caustic or acid is added to maintain the pH in a range of 5 to 9. To reduce odors and VO emissions, two 0.21-m^3 (55-gal) drums of activated carbon are used to capture vented hydrocarbon losses from these covered neutralizer tanks.

Liquid and slurry samples were collected at various locations around the WWT facility at Site 12 to characterize inlets to and outlets from the system. In addition, the vapor stream entering the carbon adsorption system (representing air emissions from the aerated lagoon controlled by the dome) was sampled. The liquid and sludge samples were collected in glass containers with Teflon-lined caps. The sample bottles were filled to minimize any headspace. Gas volumetric flow rate was determined by procedures described in EPA Reference Method 2.[31] Average gas velocity was determined following procedures outlined in Reference Method 1.[32] Gas samples were collected from the carbon adsorption system inlet and outlet two to three times daily in evacuated gas canisters.

Offsite analyses of air samples were performed on a Varian Model 3700 GC-FID/PID/HECD. Liquid samples were prepared in a purge-and-trap manner and then analyzed by GC-FID/PID/HECD.

Table F-31 summarizes the test results from the covered aerated lagoon used to evaluate the validity of Thibodeaux's model for predicting emission rates from aerated impoundments.

F.1.2.6 Site 13.[33,34] Site 13 is a large, continuously operated organic chemical complex. A test program was conducted during August 1983 on the biological WWT system at this site. It has a large flow of 14.3 x

TABLE F-31. SOURCE TESTING RESULTS[a] FOR TSDF SITE 12, COVERED AERATED LAGOON

Constituent	Influent rate to lagoon, Mg/yr	Outlet concentration, mg/L	Emission rate, Mg/yr		Emission flux rate, x 10^6 g/m^2·s		Mass transfer coefficient,[b] x 10^6 m/s	
			Materials balance	Air measurement	Materials balance	Air measurement	Materials balance	Air measurement
1,2-Dichloroethane	29	4.2	27	3.5	160	20	38	4.8
Benzene	39	0.60	39	3.2	230	18	380	30
Toluene	9.1	0.28	8.9	4.6	51	25	180	89

TSDF = Treatment, storage, and disposal facility.

[a]To perform the materials balance analysis, numerous liquid and slurry samples were collected at various locations around the Site 12 WWT facility to characterize inlets to and outlets from the system. Air emission measurements represent the average of the analyses of three gas canister samples collected from the carbon adsorption system inlet.

[b]The mass transfer coefficient is emission flux rate divided by outlet concentration.

10^6 L/d from 16 production units. The majority of the process units discharge continuously.

At the WWT system, the wastewater passes through a flowmeter and discharges into a two-stage agitated pH adjustment system where sulfuric acid or caustic is added to adjust the pH and renders the waste amenable for subsequent biological treatment. The retention time within this system averages 30 min.

After pH adjustment, the wastewater drops 0.91 m into a splitter box and gravity-flows to two of three primary clarifiers. The clarifiers remove any floating materials or organic layers from the quiescent liquid surface as well as any settleable solids. The floating materials are directed to a completely closed 114,000-L horizontal decanter. The decanted water is intermittently pumped back to the pH adjustment system. The accumulated organics in the decanter were quantitatively characterized at the end of the study. The underflow from the clarifier is pumped continuously to the primary solids settling basin (PSSB) where the solids are settled out and the supernatant is gravity-transferred to the aerated stabilization basins for further treatment. The retention time of the wastewater in the primary clarifiers averaged 2.7 h during this study.

The clarified wastewater from the primary system flows by gravity to an equalization basin. This basin is well mixed by recirculation pumps with submerged suction and discharge lines and serves to "equalize" peak loads. An oil mop located at one end of the basin may be used to reduce or eliminate floating organics not removed in the clarifiers. Although floating organics were present on the basin during this study, the oil mop was not used. At the southeast corner of the basin, the wastewater passes over an overflow weir and drops 0.6 m from a discharge pipe into a waste transfer ditch that leads to the secondary treatment area. The wastewater remains in this basin for approximately 50 h.

The wastewater is pumped from the ditch into one of two parallel aerated stabilization basins, each containing 15 aerators (3.7 to 56 kW and 7.5 to 75 kW [5 to 75 hp and 10 to 100 hp]). Approximately half of the aerators were in operation during this study. Within these basins, a microbial population capable of degrading the organics present in the waste

is maintained. The concentration of this population, measured as mixed liquor suspended solids (MLSS), was 1,000 to 2,200 mg/L. To maintain a viable biological population, both phosphorus and nitrogen are added as nutrients to the waste transfer ditch or feed line ahead of the aerated stabilization system as required. The liquid retention time in these basins was 250 hours (10.5 days).

The effluent from the aerated stabilization basins is pumped to a UNOX biological system. This system consists of four trains in parallel. Each train contains three completely enclosed reactors in series. The MLSS concentration in these reactors was on the order of 6,000 mg/L during this study, and the liquid retention time was about 27 hours.

Some key physical parameters of each WWT process unit are presented in Table F-32. The wastewater remained within this treatment facility for a total of approximately 330 hours before being discharged to the receiving water. The duration of this study represented 1.7 retention times of the wastewater within the facility.

The objective of this study was to develop a mass balance for selected organic compounds in an industrial biological WWT facility at a typical organic chemical production complex. Eight chemicals were monitored in this study, including four of high volatility (benzene, toluene, 1,2-dichloroethane, and ethyl benzene) and four of low volatility (tetralin, 2 ethyl hexanol, 2 ethyl hexyl acrylate, and naphthalene).

Sampling was conducted between August 1 and 23, 1983. Twenty-four-hour composite samples of the wastewater were collected from the influent to the treatment plant, the effluent from the primary system, the effluent from the equalization basin, the effluent from the aerated stabilization basin, and the final effluent from the treatment plant. The samples were analyzed onsite within 12 h of collection by GC. On each day of the study, total VO concentrations were measured by an organic vapor analyzer (OVA) in the ambient air upwind and downwind of each unit in the treatment facility. Air samples around the aerated stabilization basins also were collected daily on Tenax sorbent cartridges for subsequent analysis by GC-FID or GC-MS.

TABLE F-32. PHYSICAL PARAMETERS OF PROCESS UNITS AT TSDF SITE 13, WASTEWATER TREATMENT SYSTEM[35]

Inlet box & pH adjustment tanks	• Two 61-m^3 uncovered tanks • 4.6 m diameter, 3.7 m high • Each mixed with 7.5-kW (10-hp), 45-rpm agitator 0.91 m wide, 3.7 m long
Splitter box	• Open top, rectangular, water drops 1.4 m
Primary clarifiers	• Three in parallel--two usually in operation, 13.7 m diameter, 2.4 m deep
Equalization basin	• 3.6-Mg basin (3.1-Mg effective volume) • Approximately 3.4 m deep
Waste transfer ditch	• 122 m long, open ditch, 0.6 to 1.5 m deep, 1.2 to 3 m wide
Aerated stabilization basin	• Two basins in parallel--each holds 11 Mg, 3.7 m deep (MLSS 1,500 to 3,000 mg/L) Aerators--3.7 to 5.2 kW (5 to 7 hp) 7.5 to 75 kW (10 to 100 hp)
UNOX reactors	• 12 reactors in 4 parallel trains of 3 reactors each • Each reactor 9.4 m diameter by 8.5 m deep

TSDF = Treatment, storage, and disposal facility.
MLSS = Mixed liquor suspended solids.

Tables F-33, F-34, and F-35 summarize the test results from the primary clarifiers, equalization basin, and aerated stabilization basins, respectively.

F.1.3 Landfills

F.1.3.1 Site 14.[36] Site 14 is a commercial hazardous waste management facility located northeast of San Francisco, CA. The current owners took over the site in 1975. The site accepts a variety of wastes.

Emission measurements were performed on the active landfill at Site 14 on October 11 and 23, 1983. The open landfill covered approximately 19,970 m^2 and was contained within the confines of the natural topography and an earthen embankment. No liner was used because of the low permeability of the natural soil (clay). The landfill did not include any type of leachate collection system, nor any gas ventilation. This landfill had been worked for approximately 4 years. One more lift was planned for the landfill before closing it. The landfill accepted only hazardous waste, primarily inorganic pigments, solids such as organic-contaminated soils, and organic sludges. No liquids were accepted into the landfill, and no fixation was performed. Any drums received were crushed prior to placement into the landfill.

Material was unloaded in the north corner and spread over the surface by bulldozers. Compactors then went over the waste surface prior to additional waste being spread. Periodically, dirt was brought in to be mixed with the waste being spread, but no attempt was made to cover the landfill on a daily basis. Activity at the landfill was on an as-needed basis.

The objectives of the testing program were to obtain:

- Emission rate data at the active landfill using the emission isolation flux chamber approach
- Data on the concentration of VO compounds in the landfill soil/waste for comparison to compounds identified during emission measurements and as future input to predictive models.

The sampling grid was established over the eastern side of the landfill and included approximately 93 percent of the total exposed area. The western side of the landfill was only sampled at one, nonrandomly selected point (one air canister sample and corresponding soil sample)

TABLE F-33. SOURCE TESTING RESULTS[a] FOR TSDF SITE 13, PRIMARY CLARIFIERS

Constituent	Influent rate to clarifiers, Mg/yr	Outlet concentration, mg/L	Emission rate, Mg/yr		Emission flux rate, $\times 10^6$ g/m^2·s		Mass transfer coefficient,[b] $\times 10^6$ m/s	
			Materials balance	Air measurement	Materials balance	Air measurement	Materials balance	Air measurement
Tetralin[c]	0.8	0.1	<0.0	0.3	NA	28	NA	230
2-Ethyl hexanol[c]	72	22	20	8.8	2,200	950	100	43
2-Ethyl hexyl-acrylate[c]	13	1.8	<0.0	2.1	NA	230	NA	130
Naphthalene[c]	3.8	0.8	1.3	0.7	140	70	180	88
1,2-Dichloro-ethane[d]	1.2	0.5	0.3	0.01	32	1.1	64	2.2
Benzene[d]	40	16	0.8	2.8	89	300	5.6	19
Toluene[d]	8.1	2.9	0.9	1.4	100	150	34	52
Ethyl benzene[d]	27	6.9	10	2.5	1,100	270	160	39

TSDF = Treatment, storage, and disposal facility.
NA = Not available.

[a]Twenty-four-hour composite samples of the wastewater were collected from the influent to the treatment plant and the effluent from the primary clarifiers. An organic vapor analyzer was used to collect air samples within the downwind plume from the primary clarifiers on selected days.

[b]The mass transfer coefficient is emission flux rate divided by outlet concentration.

[c]Air emissions were measured for the low volatility compounds on August 18, 1983. Influent rate and outlet concentration measurements correspond to the air emission measurements.

[d]Air emissions were measured for the high volatility compounds on August 15, 17, 18, 20, and 23, 1983. Influent rate and outlet concentration measurements correspond to the air emission measurements.

TABLE F-34. SOURCE TESTING RESULTS[a] FOR TSDF SITE 13, EQUALIZATION BASIN

Constituent	Influent rate to basin, Mg/yr	Outlet concentration, mg/L	Emission rate, Mg/yr		Emission flux rate, x 10^8 g/m^2·s		Mass transfer coefficient,[b] x 10^6 m/s	
			Materials balance	Air measurement	Materials balance	Air measurement	Materials balance	Air measurement
Tetralin[c]	NA	NA	NA	NA	NA	NA	NA	NA
2-Ethyl hexanol[c]	NA	NA	NA	NA	NA	NA	NA	NA
2-Ethyl hexanol acrylate[c]	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene[c]	NA	NA	NA	NA	NA	NA	NA	NA
1-2,Dichloro-ethane[d]	1.5	0.3	0.9	0.8	5.5	4.9	18	16
Benzene[d]	40	7.1	23	10	140	61	20	8.6
Toluene[d]	9.9	1.6	6.2	10	38	61	24	38
Ethyl benzene[d]	22	3.5	14	3.1	86	19	25	5.4

TSDF = Treatment, storage, and disposal facility.
NA = Not available.

[a]Twenty-four-hour composite samples of the wastewater were collected from the influent to and the effluent from the equalization basin. An organic vapor analyzer was used to collect air samples within the downwind plume from the equalization basin on selected days.

[b]The mass transfer coefficient is emission flux rate divided by outlet concentration.

[c]Air emissions reportedly were measured for the low volatility compounds on August 12, 1983, but were not presented in the report.

[d]Air emissions were measured for the high volatility compounds on August 11 and 12, 1983. Influent rate and outlet concentration measurements correspond to the air emission measurements.

TABLE F-35. SOURCE TESTING RESULTS[a] FOR TSDF SITE 13, AERATED STABILIZATION BASINS

Constituent	Influent rate to aerated basins, Mg/yr	Outlet concentration, x 10^3 mg/L	Emission rate, Mg/yr		Emission flux rate, x 10^6 g/m^2·s		Mass transfer coefficient,[b] x 10^6 m/s	
			Materials balance	Air measurement	Materials balance	Air measurement	Materials balance	Air measurement
Tetralin[c]	NA	NA	NA	NA	NA	NA	NA	NA
2-Ethyl hexanol[d]	30.1	1,800	26.2	1.2	28	1.3	16	0.7
2-Ethyl hexyl acrylate[d]	5.1	56	4.9	6.3	5.3	6.9	95	120
Naphthalene[c]	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloro-ethane[d]	2.4	14	2.4	0.8	2.6	0.87	186	62
Benzene[d]	17	16	17	1.4	18	1.5	1,100	94
Toluene[d]	4.7	11	4.7	5.6	5.1	6.1	460	550
Ethyl benzene[d]	11	43	11	2.4	12	2.6	280	60

TSDF = Treatment, storage, and disposal facility.
NA = Not available.

[a]Twenty-four-hour composite samples of the wastewater were collected from the influent to and the effluent from the aerated stabilization basins. An organic vapor analyzer was used to collect air samples within the downwind plume from the aerated stabilization basins on selected days.

[b]The mass transfer coefficient is emission flux rate divided by outlet concentration.

[c]No air sampling results were presented for these compounds.

[d]Air emissions were measured for these compounds on August 13, 14, 16, and 17, 1983. Inlet rate and outlet concentration measurements correspond to the air emission measurements.

because of the extremely moist sampling surface and the relatively small surface area of this side. Sampling points within the grid were randomly selected. Points were chosen in 6 out of 20 grids. Duplicate air canister samples and corresponding duplicate core samples were collected at two locations; single air canister samples and corresponding core samples were collected at four locations. The area appeared to be homogeneous. The sampling locations were thought to be representative of the landfill as a whole.

The emission isolation flux chamber was used for the air emission testing. Air samples were collected in stainless-steel canisters. Soil samples were collected with a thin-wall, brass core sampler. Air and soil samples were analyzed offsite using a Varian Model 3700 GC-FID/PID/HECD. Table F-36 presents a summary of the source testing results.

F.1.3.2 Site 6.[37] Site 6 is a commercial hazardous waste TSDF. The site began operation in 1972 and was acquired by the current owner in 1979 and upgraded to accept hazardous wastes. Before a waste is accepted for disposal at the facility, samples must be analyzed to determine compatibility with the facility processes. Water-reactive, explosive, radioactive, or pathogenic wastes are not accepted. Hazardous wastes are received from the petroleum, agricultural products, electronics, wood and paper, and chemical industries.

Emission measurements were performed on the inactive landfill June 19, 1984, and on the active landfill June 21, 1984, at Site 6. Source testing was also conducted on a Site 6 surface impoundment (refer to Section F.1.1.6) and the Site 6 drum storage and handling area (refer to Section F.1.5.1).

Free liquids were not accepted for disposal to the active landfills. Any containers containing free liquids were solidified prior to disposal. The landfills accepted bulk waste solids and containerized solids. Empty drums were crushed prior to burial.

Containerized solid wastes were transported to the facility in sealed containers and unloaded directly into the assigned burial area. Containers of previously examined and tested compatible wastes were placed upright in the landfill disposal areas and covered with soil. Bulk solid wastes were

TABLE F-36. SOURCE TESTING RESULTS[a] FOR TSDF SITE 14, ACTIVE LANDFILL

Constituent	Mean emission rate, Mg/yr	Mean soil concentration, x 10^{-3} $\mu g/m^3$	Emission flux rate,[b] x 10^6 $g/m^2 \cdot s$
Tetrachloroethylene	3.3	130	5.2
Total xylene	3.8	16	6.0
Toluene	2.2	25	3.5
1,1,1-Trichloroethane	1.8	260	2.9
Ethylbenzene	1.0	.78	1.6
Total NMHC[c]	54	1,400	86

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber and soil concentrations were determined from samples collected with a thin-wall, brass core sampler.

[b]The emission flux rate is the emission rate converted to grams/second divided by the exposed surface area (19,970 m^2) of the landfill.

[c]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

placed in layers in the landfill, compacted, and covered daily with soil. Subsequent layers of solid wastes and soil cover, sloped for drainage, were added until the final landfill configuration was achieved.

At the time of testing, none of the landfills had been closed. Completed landfills had a 0.91-m native clay cover. Active landfills had approximately 0.3 m of native clay between lifts and 15.2 cm of loose cover applied daily. The landfill areas had no leachate collection systems and no gas ventilation systems.

Landfill activities at the site involved operations at three different landfills. The expansion of one landfill was operational and encompassed approximately 153,800 m^2. This active landfill was used to dispose of bulk solids, empty containers, containerized reactive and high pH materials, hydroxide filter cake, and contaminated soil. It was covered daily with 0.61 or 0.91 m of soil. The inactive landfill was completed in 1982 and has a surface area of approximately 12,140 m^2. The waste types disposed of at this site included containerized waste solvents, sludges, and toxics.

The objectives of the testing program at the Site 6 landfills were to obtain:

- Emission rate data at the inactive landfill using the emission isolation flux chamber approach
- Data on the concentration of VO in the inactive landfill soil for comparison to compounds identified during emission measurements
- Emission rate data at the active landfill using the emission isolation flux chamber approach
- Data on the concentrations of VO compounds in the active landfill soil for comparison to compounds identified during emission measurements.

The inactive landfill was an elliptical area of nominally 2,370 m^2. The area was divided into 25 equal grids. Sampling locations were selected randomly and were thought to be representative of the overall landfill. Air emission measurements were made at two grid points (one air canister sample at each point), and a single soil core sample was collected at a different point. Therefore, the soil sample did not correspond to the air emission samples.

The active landfill was relatively homogeneous, but for sampling purposes it was divided into two areas. The temporary storage area had not received fresh waste in 1 to 2 days. The surface area of the temporary storage area was 1,490 m^2. It was divided into eight equal grids, from which three were randomly selected for air emission measurements (single air canister samples at each grid). Corresponding single soil cores were obtained at each of the three grid points. The active working area had a surface area of 670 m^2. Corresponding single air emission measurements and soil sampling were conducted at one location selected by visual inspection due to time limitations.

The emission isolation flux chamber approach was used in testing air emissions. Gas samples were collected in evacuated stainless-steel canisters. Soil samples were collected with a thin-wall, brass core sampler. Gas and soil samples were analyzed offsite using a Varian Model 3700 GC-FID/PID/HECD. Table F-37 summarizes the source testing results for the inactive landfill. Tables F-38 and F-39 summarize the source testing results for areas 1 and 2, respectively, of the active landfill.

F.1.3.3 Site 15.[38,39] Site 15 is a commercial waste disposal operation that services four industrial clients exclusively. The site is located in the Gulf Coast area and includes both a land treatment area and a landfill. It has been in operation since 1980. Tests were conducted on the land treatment area and the landfill during the week of November 14, 1983. The land treatment source testing is discussed in Section F.1.4.5.

The landfill that was tested at Site 15 consists of multiple cells with overall dimensions of 549 by 152 by 4.6 m deep.

At the time of the tests, the active cells in the landfill included:

- A = centrifuge filter cake
- B = polymerization catalysts
- C = reduced metal catalysts
- D = miscellaneous.

Cell A consists of a rectangular pit with nominal dimensions of 15.2 by 12.2 by 3.0 m deep. Wastes disposed of in cell A were expected to

TABLE F-37. SOURCE TESTING RESULTS[a] FOR TSDF SITE 6, INACTIVE LANDFILL

Constituent	Mean emission rate, x 10^3 Mg/yr	Emission flux rate,[b] x 10^9 g/m^2•s
Methylene chloride	10	130
1,1,1-Trichloroethane	5.3	71
Total NMHC[c]	56	750

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber.

[b]The emission flux rate is the emission rate converted to grams/second divided by the surface area (2,370 m^2) of the inactive landfill.

[c]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

TABLE F-38. SOURCE TESTING RESULTS[a] FOR TSDF SITE 6, ACTIVE LANDFILL, TEMPORARY STORAGE AREA

Constituent	Mean emission rate, x 10^3 Mg/yr	Mean soil concentration, $\mu g/m^3$	Emission flux rate,[b] x 10^9 $g/m^2 \cdot s$
Toluene	3.4	ND	73
Ethylbenzene	5.9	ND	130
Total xylene	30	ND	650
Methylene chloride	20	1,200	430
Chloroform	2.6	ND	56
1,1,1-Trichloroethane	120	ND	2,600
Tetrachloroethylene	30	0.65	650
Total NMHC[c]	660	18,000	14,000

TSDF = Treatment, storage, and disposal facility.
ND = Not detected.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber and soil concentrations were determined from samples collected with a thin-wall, brass core sampler.

[b]The emission flux rate is the emission rate converted to grams/second divided by the surface area (1,470 m^2) of the active landfill temporary storage area.

[c]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

TABLE F-39. SOURCE TESTING RESULTS[a] FOR TSDF SITE 6, ACTIVE LANDFILL, ACTIVE WORKING AREA

Constituent	Emission rate, x 10^3 Mg/yr	Soil concentration, $\mu g/m^3$	Emission flux rate,[b] x 10^9 $g/m^2 \cdot s$
Vinyl chloride	19	ND	900
Methylene chloride	200	ND	9,500
Chloroform	34	ND	1,600
1,1,1-Trichloroethane	680	ND	32,000
1,2-Dichloropropane	3.8	ND	180
Tetrachloroethylene	270	ND	13,000
Total NMHC[c]	1,400	31,000	66,000

TSDF = Treatment, storage, and disposal facility.
ND = Not detected.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber and soil concentrations were determined from samples collected with a thin-wall, brass core sampler.

[b]The emission flux rate is the emission rate converted to grams/second divided by the surface area (670 m^2) of the active landfill active working area.

[c]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

include solids from acrylonitrile, acetone cyanohydrin, lactic acid, tertiary butylamine, and iminodiacetic acid production activities. Waste is typically unloaded with cell A four to eight times per month. During the test period, a single truckload of waste was unloaded. The waste covered approximately 25 percent of the floor of the cell and was left uncovered.

The objectives of the test program at cell A were to provide data to evaluate both measurement and modeling techniques for determining air emissions from hazardous waste landfills and to provide an indication of the air emission levels from cell A. Gas-phase sampling was performed by the emission isolation flux chamber method, and solid grab samples were collected. For the flux chamber sampling, cell A was divided into 20 equal grids, and samples (single air canister samples) were collected from two of the grids. Nine solid grab samples were collected, of which two were selected for detailed analysis. Only one of the solid samples selected for detailed analysis corresponded to a flux chamber measurement.

Gas samples were collected in evacuated stainless-steel canisters. Solid samples were collected in glass VOA vials with Teflon-lined caps and filled with material so that no headspace was present. Gas and solid sample offsite analysis was done using a Varian Model 3700 GC-FID/PID/HECD. Table F-40 presents the source testing results from cell A of the Site 15 landfill.

F.1.3.4 Site 16.[40,41] Site 16 is a commercial hazardous waste management facility located in the northeastern United States. The site includes four chemical landfills with provisions for a fifth. Landfills M, N, and O were closed in 1978, 1980, and 1982, respectively. Landfill P was opened in February 1982. At the time of the test, the categories of waste placed in landfill P included:

- Flammables--paint waste, etc. (flashpoints from 27 to 60 °C)
- Pseudo metals--cyanide, arsenic, etc. (no longer an active cell)
- Toxics--polychlorinated biphenyls (PCB), pesticides, etc.
- General organics--flashpoints greater than 60 °C
- Heavy metals--oxidizers, WWT sludge.

TABLE F-40. SOURCE TESTING RESULTS[a] FOR TSDF SITE 15, ACTIVE LANDFILL, CELL A

Constituent	Emission rate, x 10^6 Mg/yr	Soil concentration, μg/g	Emission flux rate,[b] x 10^9 g/m^2•s
Acrylonitrile	<370	1.5	<63
Benzene	540	0.21	93
Toluene	<370	0.69	<63
Ethylbenzene	<370	0.29	<63
All xylene	<740	1.9	<130
Styrene	<370	0.67	<63
Isopropylbenzene	<370	0.73	<63
n-Propylbenzene	<370	0.32	<63
Naphthalene	ND	0.51	ND
Chlorobenzene	<370	ND	<63
Acetaldehyde	1,100	ND	190
Total NMHC[c]	4,800	31	820

TSDF = Treatment, storage, and disposal facility.
ND = Not detected.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber and soil concentrations were determined from a sample collected in a glass VOA vial.

[b]The emission flux rate is the emission rate converted to grams/second divided by the surface area (185 m^2) of cell A.

[c]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

Liquids were not accepted in landfill P. The waste material was limited to 5 percent free fluid, which included air (previous value had been 10 percent). Liquid wastes were solidified prior to disposal. Municipal wastes were kept separate from the chemical waste and disposed of in the sanitary landfill.

Testing was performed at landfills P and O on October 11 and 12, 1983. At the time of testing, landfill P was 240 by 160 by 8.5 m deep at grade and had a volume of 3.3×10^5 m^3. The landfill has a 3.2-ha bottom and was 4 ha at the top of the berm. Major categories of waste were disposed of in distinct subcells. The area allocated for each type of waste in landfill P was nominally:

- Heavy metals--35 percent
- General organics--35 percent
- Flammables--20 percent
- Toxics--10 percent.

A 15.2-cm cover was placed over the disposed waste daily to minimize exposure to the atmosphere. The cover could consist of soils, ashes, lime, hydrated carbon, or low-level contaminated soils.

Chemical landfill O is typical of the inactive landfills at Site 16. Landfill O was closed in 1982 and occupies approximately 2 ha. Wastes were segregated into subcells for general waste categories as described for landfill P. The final cap of the landfill includes 0.9 m of compacted clay, a 0.2-cm high-density polyethylene (HDPE) liner, 0.5 m of loose clay, and 15.2 cm of topsoil and vegetation. The design permeability of the cap is 1×10^{-7} cm/s.

Closed landfills at Site 16 include both standpipes for leachate collection and gas vents. There are two standpipes in each of the five subcells, for a total of 10. The standpipes are 61 cm diameter and open to the atmosphere. There are two gas vents per subcell, for a total of 10. The gas vents are valved shut, with provisions for gas release through carbon canisters if the gas pressure builds up within the subcells.

The objectives of the test program at landfills O and P were to provide data to evaluate both measurement and modeling techniques for

determining air emissions from inactive and active hazardous waste landfills and to provide an indication of the air emission levels from landfills O and P.

Emission measurements were made at the inactive chemical landfill O using the flux chamber and vent sampling techniques. No emissions were detected as measured by the flux chamber with continuous total hydrocarbon (THC) monitor; therefore, no syringe or canister samples were taken. Sixteen vents were sampled, at least one vent from each cell. Fifteen samples by real-time hydrocarbon analyzer and one canister and two syringe samples were collected. No solid samples were collected.

Emission sampling at the active chemical landfill P was limited to two flux chamber measurements in the flammable cell only. One canister and two syringe samples were collected. No solid samples were collected. No attempt was made to grid the area. The nominal surface area of the active landfill was 38,000 m^2.

Canister samples were analyzed offsite using a Varian Model 3700 GC-FID/PID/HECD. Syringe samples were analyzed onsite by GC-FID. Table F-41 presents the results of the canister sample collected from a standpipe in the general organic cell of landfill O. Table F-42 presents the results of the canister sample collected from the flux chamber over the flammable cell of landfill P. The nonmethane hydrocarbon (NMHC) totals represent averages of the canister and syringe samples.

F.1.3.5 Site 7.[42,43,44] Site 7 is a commercial hazardous waste management facility located in the northeastern United States. The site was developed for hazardous waste operations in the early 1970s. Site 7 has a total of nine chemical landfills. Seven are closed, one is under construction, and one is active (landfill B). Tests were conducted at landfill B and one of the closed landfills (landfill A) during the first week of October 1983. Also at Site 7, tests were conducted on three surface impoundments in the WWT system (refer to Section F.1.1.7) and on the drum storage building (refer to Section F.1.5.3).

When the tests were conducted, landfill B covered an estimated 2.5 ha, with dimensions of 128 by 168 by 10.4 m at completion. The waste was segregated into subcells according to the general category of the waste.

TABLE F-41. SOURCE TESTING RESULTS[a] FOR TSDF SITE 16, INACTIVE LANDFILL O

Constituent	Emission rate, x 10^3 Mg/yr
Benzene	3.3
Toluene	230
Ethylbenzene	9.7
Total xylene	28
Styrene	3.9
n-Propylbenzene	3.0
Methylene chloride	220
Chloroform	7.4
1,1,1-Trichloroethane	3.4
Total NMHC[b]	930

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.

[a]This table presents the results of the analysis of a single canister sample collected from a standpipe in the general organic cell.

[b]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

TABLE F-42. SOURCE TESTING RESULTS[a] FOR TSDF SITE 16, ACTIVE LANDFILL P, FLAMMABLE WASTE CELL

Constituent	Emission rate, x 10^3 Mg/yr	Emission flux rate,[b] x 10^9 g/m^2•s
Toluene	100	420
Total xylene	190	790
Methylene chloride	380	1,600
1,1,1-Trichloroethane	51	210
Tetrachloroethylene	250	1,000
Total NMHC[c]	1,900	7,900

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber. One air canister sample was collected from the flammable waste cell. No soil samples were collected.

[b]The emission flux rate is the emission rate converted to grams/second divided by the surface area (7,600 m^2) of the flammable waste cell.

[c]The NMHC totals do not represent column sums because only major constitutents (in terms of relative concentrations) are presented.

Table F-43 lists the subcells' percent of area occupied, types of wastes accepted, and cover material at the time of the testing. The waste accepted included both drums and bulk fill. Municipal waste was not accepted. Waste was being disposed of at landfill B at a rate of 6,900 m^3/mo.

All cells of landfill B were active during the sampling at Site 7. The activity in the landfill and type and form of waste disposal (bulk vs. drum) was dependent on the waste received. Drums were unloaded from semi-trailers via towmotor with drum grabbers and positioned in the suitable cell for disposal. The drums were used in alternating layers (drum layer, bulk waste layer), giving the cell structural integrity. Some drums were crushed in place after delivery using earth-moving equipment. Layers of waste were covered with 15.2 cm of clay or low-level contaminated soils on a daily basis, leaving little waste exposed to the atmosphere. The internal berms of landfill B were being increased (in height) allowing for filling at different rates.

Chemical landfill A is one of seven inactive landfills at Site 7. Landfill A was built in September 1978, covers 2.6 ha of surface area, and contains 371,000 m^3 of waste. The landfill has subcells for general waste categories as previously described for landfill B. The final cap of the landfill includes 0.9 m of compacted clay, a 5.1-μm PVC liner, 0.46 m of uncompacted clay, and 15.2 cm of topsoil/sod. The design permeability of this cap is 1×10^{-7} cm/s. During the field test, a new cap was being installed. The capping process was essentially complete, with the topsoil being finished off.

Closed landfills at Site 7 include a gas collection system with open vents and a leachate collection system. The gas collection system has a total of 18 vents, with each subcell vented individually. The vents are 15.2-cm schedule 40 PVC pipe. The leachate collection system has one well for each subcell for a total of seven. Leachate is pumped directly to the WWT system. Table F-44 lists the purgeable organics (as measured by EPA Method No. 624) reported by Site 7 in the leachate from chemical landfill A.

TABLE F-43. DESCRIPTION[a] OF TSDF SITE 7, DESCRIPTION OF SUBCELLS IN ACTIVE LANDFILL B[45]

Subcell	Percent of area occupied	General waste category	Waste description	Composition of cover
No. 1	40	Heavy metals	Cadmium, chromium, copper, cobalt, iron, lead, manganese, mercury, nickel, tin, etc.	65% soil 35% neutralized salts
No. 2	10	Pseudo metals	Antimony, arsenic, beryllium, bismuth, phosphorus, selenium, tellenium	Soils with calcium carbonate waste solids
No. 3	25	General wastes	Nonhalogenated aromatics, hydroxyl and amine derivatives, acid aldehydes, ketones, flashpoint greater than 54 °C	65% soil 35% neutralized salts
No. 4	15	Halogenated wastes	Controlled organics with flashpoint greater than 54 °C not suitable for fuel, PCB-contaminated soils	65% soil 35% neutralized salts
No. 5	10	Flammable wastes	Organics with flashpoints greater than 27 °C and less than 54 °C not suitable for fuel	65% soil 35% neutralized salts

TSDF = Treatment, storage, and disposal facility.
PCB = Polychlorinated biphenyls.

[a]Characteristics of the active landfill B subcells at the time source testing was conducted.

TABLE F-44. PURGEABLE ORGANICS[a] REPORTED IN LEACHATE FROM CHEMICAL LANDFILL A AT TSDF SITE 7[46]

Compound	Mean concentrations, μg/L
Chloromethane	<10
Bromomethane	<10
Vinyl chloride	<10
Chloroethane	<10
Methylene chloride	25,295
Trichlorofluoromethane	189
1,1-Dichloroethene	55
1,1-Dichloroethane	944
Trans-1,2-Dichloroethene	4,061
Chloroform	2,193
1,2-Dichloroethane	7,596
1,1,1-Trichloroethane	502
Carbon tetrachloride	64
Bromodichloromethane	50
1,2-Dichloropropane	89
Trans-1,3-Dichloropropene	50
Trichloroethene	2,493
Cis-1,3-Dichloropropene	150
1,12-Trichloroethane	90
Benzene	1,842
2-Chloroethylvinyl ether	<10
Bromoform	50
Tetrachloroethene	941
1,1,2,2-Tetrachloroethane	3,357
Toluene	4,378
Chlorobenzene	559
Ethylbenzene	1,427

TSDF = Treatment, storage, and disposal facility.

[a]Measured by EPA Method 624.

The major compounds found were methylene chloride, trans-1,2-dichloroethene, chloroform, 1,2-dichloroethane, trichloroethane, benzene, 1,1,2,2-tetra-chloroethane, and toluene. In the wastes disposed of in the landfill, these compounds were typically present in higher concentrations than the other purgeable organics.

The objectives of the test program at landfills A and B were to provide data to evaluate both measurement and modeling techniques for determining air emissions from inactive and active hazardous waste landfills and to provide an indication of the air emission levels from landfills A and B.

Emission measurements were made at the inactive chemical landfill A using both vent sampling and flux chamber techniques. Each of the 18 vents was surveyed using a real-time hydrocarbon analyzer and syringe, and single canister samples were collected from two vents in the general organic cell. Single-flux chamber measurements were made in the toxic and general organic cells. No emissions were detected by the flux chamber measurements. No solid samples were collected.

Emission measurements were made at active landfill B using flux chamber techniques. The flammable and general organic cells were gridded, and single canister samples were taken in one of four grids in the flammable cell and in two of nine grids in the general organic cell. Single soil samples also were collected in glass VOA vials during the flux chamber measurements. The exposed surface area of the flammable cell was 2,100 m^2 and of the general organic cell 4,200 m^2.

No emissions through the cap of inactive landfill A were detected using the flux chamber technique. The canister samples were taken from two vents and were analyzed offsite using Varian Model 3700 GC-FID/PID/HECD. Table F-45 presents the results of the analyses.

The canister and soil samples from the flux chamber testing at active landfill B were analyzed using Varian Model 3700 GC-FID/PID/HECD. Tables F-46 and F-47 present the results of the analyses for the flammable and general organic cells, respectively.

TABLE F-45. SOURCE TESTING RESULTS[a] FOR TSDF SITE 7, INACTIVE LANDFILL A

Constituent	Vent 2A emission rate, x 10^6 Mg/yr	Vent 3-2 emission rate, x 10^9 Mg/yr
Benzene	730	840
Toluene	280	2,800
Total xylene	130	3,600
1,1-Dichloroethylene	140	ND
Methylene chloride	11,000	27,000
Chloroform	3,100	1,200
1,1,1-Trichloroethane	3,100	550
Tetrachloroethylene	1,100	620
1,1-Dichloroethane	1,200	ND
Acetaldehyde	58	ND
Total NMHC[b]	44,000	220,000

TSDF = Treatment, storage, and disposal facility.
ND = Not detected.
NMHC = Nonmethane hydrocarbon.

[a]This table presents the results of the analysis of vent samples collected during source testing at the TSDF Site 7 inactive landfill A. Single canister samples were collected from two vents in the general organic cell.

[b]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

TABLE F-46. SOURCE TESTING RESULTS[a] FOR TSDF SITE 7, ACTIVE LANDFILL B, FLAMMABLE WASTE CELL

Compound	Emission rate, x 10^6 Mg/yr	Soil concentration, x 10^3 μg/g	Emission flux rate,[b] x 10^9 g/m^2•s
Toluene	62,000	ND	940
Ethylbenzene	17,000	220	260
Total xylene	57,000	11,000	860
Styrene	13,000	ND	200
Isopropylbenzene	3,700	430	56
n-Propylbenzene	5,300	1,400	80
Naphthalene	600	1,000	9.1
Methylene chloride	5,900	ND	89
1,1,1-Trichloroethane	110,000	97	1,700
Tetrachloroethylene	170,000	12,000	2,600
Total NMHC[c]	700,000	220,000	11,000

TSDF = Treatment, storage, and disposal facility.
ND = Not detected.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber and soil concentrations were determined from samples collected in glass volatile organic analysis vials.

[b]The emission flux rate is the emission rate converted to grams/second divided by the surface area (2,100 m^2) of the flammable waste cell.

[c]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

TABLE F-47. SOURCE TESTING RESULTS[a] FOR TSDF SITE 7, ACTIVE LANDFILL B, GENERAL ORGANIC WASTE CELL

Compound	Mean emission rate, x 10^3 Mg/yr	Mean soil concentration, μg/g	Mean emission flux rate,[b] x 10^9 g/m^2•s
Benzene	8.4	ND	63
Toluene	490	10	3,700
Ethylbenzene	890	39	6,700
Total xylene	4,300	200	32,000
Styrene	1,800	87	14,000
Isopropylbenzene	48	4.4	360
n-Propylbenzene	100	8.2	760
Naphthalene	4.4	14	33
Methylene chloride	97	1.0	730
1,1,1-Trichloroethane	59	ND	450
Tetrachloroethylene	1.5	1.6	11
Total NMHC[c]	9,600	1,200	72,000

TSDF = Treatment, storage, and disposal facility.
ND = Not detected.
NMHC = Nonmethane hydrocarbon.

[a]Air emissions were sampled with a flux chamber and soil concentrations were determined from samples collected in glass volatile organic analysis vials.

[b]The emission flux rate is the emission rate converted to grams/second divided by the surface area (4,200 m^2) of the general organic cell.

[c]The NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

F.1.4 Land Treatment

F.1.4.1 Site 17.[47] A study from 1986 to 1987 by a corporate research facility consisted of a bench-scale laboratory simulation of a land treatment operation. The goals of that simulation were to measure air emissions that result from current land treatment practices, to determine the effectiveness of land treatment as a means of biologically degrading refinery sludges, and to measure the effectiveness of potential emission control strategies, including centrifugation and thin-film evaporation (TFE). The test setup consisted of two soil boxes, each with a surface area of approximately 0.46 m^2. Soil and waste from a company-owned land treatment operation were placed in the soil boxes for testing. For each test, ambient air that was treated to remove carbon dioxide (CO_2) and hydrocarbons was circulated over the soil boxes at regulated conditions. Installed instrumentation was used to monitor air flow and temperature profiles in the boxes and to obtain samples of the air both upstream and downstream of the soil boxes. The air samples were analyzed for hydrocarbons using GC-FID and for CO_2 using gas chromatograph-thermal conductivity detector (GC-TCD). Prior to application of waste to the soil surface, the waste was analyzed by the modified oven drying technique[48] (MODT) to determine the oil, water, and solids content and by gravimetric purge and trap to determine the VO content.

For the first test, only one soil box was used, and API separator sludge (RCRA waste code K051) was applied using subsurface injection, which is the normal method of waste application by the company. For the second test, two soil boxes were used. API separator sludge was applied to one box, and API separator sludge treated in a laboratory to simulate a centrifuge and drying operation was applied to the other box. In a third test, emissions were measured from samples of an oily waste that had been processed by TFE in a previous study of TFE (described in Section F.2.3.3.1). Two samples of TFE-processed waste were evaluated: one that was generated under operating conditions of high feed rate and low temperature, and one generated under conditions of low feed rate and high temperature. The first test was continued for about 2-1/2 months, the second was continued for 22 days, and the third was continued for 26 days.

The results of the sludge analyses for the test runs are presented in Table F-48. Table F-49 presents the cumulative emissions over the test period and the weight fraction of applied oil emitted over the test period.

F.1.4.2 Site 18.[49] In 1986, bench-scale laboratory experiments were set up to simulate a land treatment operation. The objectives of the study were to:

- Measure air emissions of total and specific VO from land-treated refinery sludges
- Correlate the measured emissions with the total and specific VO
- Document the presence of bioactivity in the soil/sludge mixture.

The simulation was carried out using four identical soil boxes that were enclosed and instrumented to control and monitor experimental conditions. Airflow over the soil, temperature, and humidity were controlled to preselected values. The concentration of VO in the air downstream of the soil boxes was monitored and used to estimate total VO emissions. In one test run, samples of the air downstream of the soil boxes were collected in canisters and analyzed for specific VO constituents. Measured emissions were correlated with results of analyses of the applied waste.

Two different test runs were made using soil and sludge from two different land treatment operations. In each test, land treatment soil was placed in each of the four soil boxes, and sludge was applied to three of the soil boxes. Two of the boxes with sludge applied served as duplicate tests, and the third was treated with mercuric chloride to eliminate (or reduce) bioactivity in the soil. The fourth box had no sludge applied and was used as a control box.

Each test was continued for 31 days, during which time emission rates were measured on a semicontinuous basis using THC analyzers. After sludge was applied to a soil box, it remained on top of the soil for 24 hours and then was mixed into the soil to simulate tilling. Additional "tillings" were carried out at 8 and 15 days after waste application. Analyses of the raw sludge were made using several different analytical methods, and the results were compared with measured VO emissions over the entire test

TABLE F-48. WASTE ANALYSES[a] OF PETROLEUM REFINERY SLUDGES USED IN LAND TREATMENT TESTS AT SITE 17

Waste constituent	Percent composition, wt %				
		Test 2		Test 3	
	Test 1 API separator sludge	API separator sludge	Centrifuged waste[b]	TFE-processed waste[c]	TFE-processed waste[d]
Oil	6.8	8.8	10.9	17.4	67.3
Water	71.3	78.4	0.9	80.5	17.8
Solids	21.9	13.2	88.4	2.2	15.2
VO	2.4	2.5	0.2	NA	NA

Note: Test numbers do not correspond to those used in the test report.

VO = Volatile organic.
TFE = Thin film evaporator.
NA = Not analyzed.

[a]The oil, water, and solids content was determined using the modified oven drying technique. The volatile organic content was determined using gravimetric purge and trap technique.

[b]API separator sludge, treated to simulate a centrifuge and drying operation, was used.

[c]Oily waste processed by TFE under conditions of high feed rate and low temperature.

[d]Oily waste processed by TFE under conditions of low feed rate and high temperature.

TABLE F-49. MEASURED AIR EMISSIONS[a] FROM LAND TREATMENT LABORATORY SIMULATION AT SITE 17

Test No.	Test duration, d	Emissions	
		Cumulative, kg[b]	Wt % of applied oil[c]
Test 1, API separator sludge	69	0.38	40
Test 2, API separator sludge	22	0.06	11
Test 2, centrifuged waste[d]	22	0.005	1
Test 3, TFE-processed waste[e]	26	0.005	1
Test 3, TFE-processed waste[f]	26	0.01	2

Note: Test numbers do not correspond to those used in the test report.

[a]Laboratory simulation of land treatment operation using subsurface injection.

[b]Air samples analyzed for hydrocarbons by gas chromatograph-flame ionization detector and for CO_2 by gas chromatograph-thermal conductivity detector.

[c]Weight fraction of applied oil emitted over test period.

[d]API separator sludge, centrifuged and dried before testing.

[e]Oily waste processed by TFE under conditions of high feed rate and low temperature.

[f]Oily waste processed by TFE under conditions of low feed rate and high temperature.

period. In the second test run, GC-MS analyses were made of both the raw sludge and the air downstream of the soil beds to determine the fraction of VO in the applied waste that is emitted during the test.

Table F-50 shows the makeup of the waste used in each of the test runs as determined by the modified oven drying technique. For Run 1, the waste was an API separator sludge; for Run 2, the waste was an induced air flotation (IAF) sludge.

Table F-51 summarizes the results of the two test runs. For each test, the table presents the oil (organic) loading on each soil box as determined from the modified oven drying technique sludge analysis, the cumulative emissions from each soil box over the test period, and the percent of applied oil emitted from each box over the test period.

F.1.4.3 Site 19.[50] From June 25 through July 5, 1985, field experiments were conducted at Site 18, an active midwestern refinery that has a crude-oil-processing capacity of approximately 14.3 million L/d (90,000 bbl/d). Operations conducted at the facility include atmospheric distillation, vacuum distillation, delayed coking, fluid catalytic cracking, catalytic reforming, aromatic isomerization, lube oil processing, and asphalt processing.

The field study used a test plot that has been used routinely in the past for land treatment of oily refinery sludges. Most of the sludge applied to the site in the last 3 years has been an oily WWT sludge composed of API separator and dissolved air flotation (DAF) bottom sludges with an average composition of 71 percent water, 22 percent oil, and 7 percent solids. The field test plot also receives biological sludge from an onsite activated sludge plant two to three times a year. Single monthly sludge applications of 3,180 to 3,980 L (20 to 25 bbl) of oil per plot, or approximately 39,300 L/ha (100 bbl/acre), are normal during warm periods. This is equivalent to 11,900 L of sludge per plot (75 bbl of sludge per plot). In cold weather, loadings are routinely half these rates. Plots are generally tilled within a few days of surface waste application. A second tilling is usually carried out 2 to 3 weeks later. A 4-week treatment period from the first tilling event is generally used before waste is reapplied in a given location.

TABLE F-50. WASTE ANALYSES[a] OF PETROLEUM REFINERY SLUDGES USED IN LAND TREATMENT LABORATORY SIMULATION AT SITE 18

Waste constituent	Percent composition, wt %	
	Run 1[b]	Run 2[c]
Oil	29.5	21.3
Water	65.0	69.7
Solids	5.5	9.0

[a]The oil, water, and solids content was determined using the modified oxygen drying technique.

[b]American Petroleum Institute separator sludge was used.,

[c]Induced air flotation float was used.

TABLE F-51. TOTAL VO EMISSIONS AT 740 HOURS AFTER APPLICATION OF PETROLEUM REFINERY SLUDGES TO LAND TREATMENT SOIL BOXES, SITE 18

Test run/ soil box[a]	Test duration, h	Oil loading, kg oil/m^2[b]	Total VO emissions at 740 h,[c] kg	Percent of total oil applied emitted	Percent of total VO applied emitted
Run 1[d]	740				
Box 1		9.58	0.14	5.2	19
Box 2		No sludge applied	Negligible	NA	NA
Box 3		9.47	0.17	6.5	27
Box 4		9.71[e]	0.20	7.4[e]	33
Run 2[d]	740				
Box 1		5.68	0.29	18	41
Box 2		No sludge applied	0.05	NA	NA
Box 3		5.57	0.29	19	56
Box 4		5.32	0.32	22	49

VO = Volatile organics.
NA = Not applicable.

[a]For Run 1, American Petroleum Institute (API) separator sludge was surface-applied. For Run 2, induced air flotation sludge was surface-applied.

[b]As measured using the modified oven drying technique (MODT).

[c]Based on emissions associated with the sludge only (i.e., VO emissions from Box 1, 3, or 4 minus the VO emissions from control Box 2). VO concentrations were measured using two Byron Instrument Analyzers. During the first 24 h after sludge application, a real-time total hydrocarbon analyzer (Byron 401 analyzer) measured emissions once per minute. Long term monitoring was done using a Byron 301 analyzer, with an average total hydrocarbon measurement made approximately once per hour. (An average measurement consisted of the average of five individual measurements taken during that period.)

[d]Sludge applied to Box 1 and Box 3 as duplicate tests; sludge treated with mercuric chloride to eliminate (or reduce) bioactivity applied to Box 4 and no sludge applied to Box 2.

[e]Average MODT results used rather than MODT results for Box 4.

The specific objectives of the project were to:

- Evaluate a type of flux chamber for measuring air emissions at hazardous waste land treatment facilities in conjunction with emission source testing, compliance monitoring, and model validation activities

- For seven waste constituents, evaluate the Thibodeaux-Hwang air emission model in field studies using actual hazardous wastes to determine its applicability and limitations relative to the prediction of full-scale hazardous air emissions from land treatment facilities.

The test plot was approximately 6 m by 182 m and was divided in half lengthwise with three emission measurement locations per half to conform with waste application methods normally used by the refinery. Waste applications were made independently to each side of the field plot using gravity feed from a tank truck equipped with a slotted application pipe approximately 3 m in length and 8 cm in diameter. Each side of the application area received a full truckload of waste corresponding to approximately 3,330 L as reported by the tank truck operator.

Tilling was conducted approximately 24 h after waste application and again approximately 155 h after waste application due to rainfall that had occurred following the first tilling. Tiller depth ranged from approximately 17 cm to approximately 23 cm.

The application area was subdivided into six subsections, with each subsection further subdivided into 396 grid locations of 0.69 m by 0.69 m. Six sampling flux chambers were used for sample collection at randomly chosen grid locations. The same sample locations were used throughout the test program to preserve spatial continuity of the data collected. Four distinct sampling phases were conducted:

- Background sampling of the test site prior to tillage

- Background sampling of the test site following tillage and prior to waste application

- Specific constituent emission sampling following waste addition

- Specific constituent emission sampling following each of two tilling operations.

Tenax sorbent tubes were used to collect the air emission samples to be used for quantifying seven constituents. The constituents that were quantified are identified in Table F-52.

In addition to the flux chamber sampling of air emissions, soil samples and samples of the waste applied during field testing were collected for analysis. The soil samples were analyzed for particle size distribution, particle density, oil and grease, and specific constituents. Air emission and waste samples were analyzed by GC-FID.

Table F-52 presents the concentration of specific organic constituents in the hazardous waste applied during field testing. The values represent averages of 10 waste samples. Figure F-5 presents measured emission flux data over time for one test plot over one testing period. Data for other tests show similar trends. Table F-53 presents cumulative emissions for each constituent monitored and shows the weight fraction emitted for each constituent over the test period. These test results show wide variations among the different measurement locations in the weight fraction of applied constituents emitted to the air. In a few instances, values of measured emissions of a constituent are greater than measured values of the amount applied. This anomaly exists for ethylbenzene at all sampling locations and for benzene at three sampling locations. No clear reason for these anomalies are evident in the test report. Oil in the soil prior to the application of waste for the test would contribute to measured emission values and could account for part of the reported results. Emission data for the test show most of the measured emissions occurred during the first 24 hours of the test before the waste was tilled into the soil.

F.1.4.4 Site 20.[52] In 1984, field tests of land treatment emissions were conducted at Site 20, a West Coast commercial crude oil refinery producing a variety of hydrocarbon products. Refinery wastewater treatment sludges, some of which are RCRA-listed hazardous wastes, are applied to an onsite land treatment plot using subsurface injection.

The applied waste is typically 50 to 75 percent DAF/API float, 20 to 30 percent separator cleanings, and about 5 percent miscellaneous oily waste. The sludge composition is typically about 76 percent water, 12 percent solids, and 12 percent oil (boiling curves usually start about

TABLE F-52. WASTE ANALYSIS, CONCENTRATION OF VOLATILE ORGANIC CONSTITUENTS IN PETROLEUM REFINERY SLUDGES[a] APPLIED IN LAND TREATMENT FIELD EXPERIMENTS AT TSDF SITE 19[51]

Constituent[b]	Concentration, μg/g waste[c]
Benzene	249
Toluene	631
Ethylbenzene	22
p-Xylene	33
m-Xylene	181
o-Xylene	56
Naphthalene	124

TSDF = Treatment, storage, and disposal facility.

[a]Waste was a combination of American Petroleum Institute separator sludge and dissolved air flotation sludge.

[b]Constituent analysis done using gas chromatograph-flame ionization detector.

[c]Each concentration is the average of 10 waste samples.

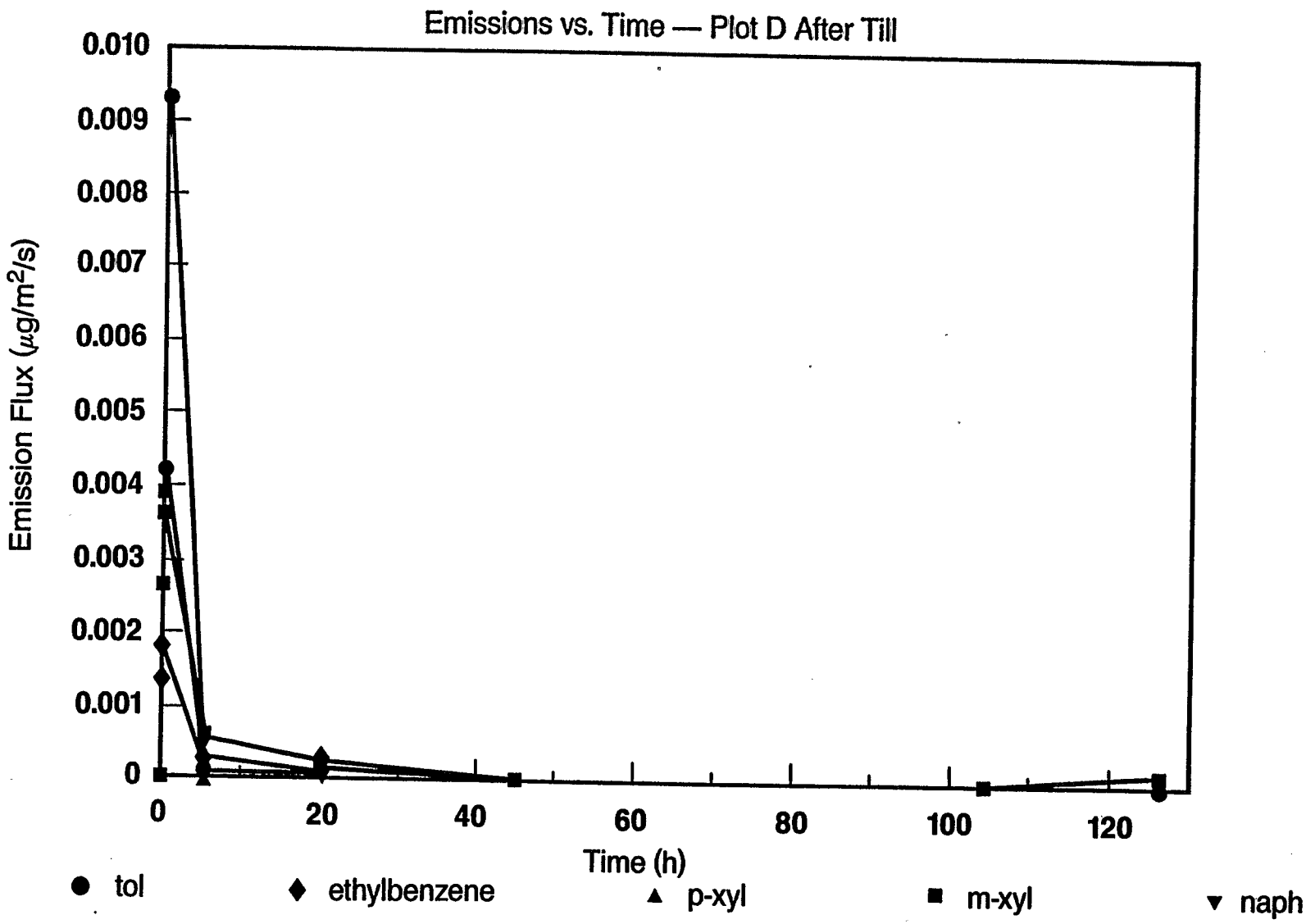

Figure F-5. Measured emission flux for one plot over one test period at Site 19.

TABLE F-53. RESULTS OF PETROLEUM REFINERY SLUDGE LAND TREATMENT FIELD EXPERIMENTS[a] AT TSDF SITE 19

Test location	Cumulative emissions[b]													
	Benzene[c]		Toluene		Ethylbenzene[c]		p-Xylene		m-Xylene		o-Xylene		Naphthalene	
	$\mu g/cm^2$	wt %	$\mu g/cm^2$	wt %	$\mu g/cm^2$	wt %	$\mu g/cm^2$	wt %	$\mu g/cm^2$	wt %	$\mu g/cm^2$	wt %	$\mu g/cm^2$	wt %
A	272	81	349	41	58	195	7	16	96	39	21	28	2	1
B	300	110	454	66	96	402	8	21	164	83	23	38	2	2
C[d]	188	39	210	17	59	140	16	25	87	25	19	17	3	1
D	456	141	703	86	101	353	24	55	185	79	38	52	3	2
E	382	106	576	63	109	345	21	43	136	52	32	39	2	1
F	325	84	465	47	72	208	7	13	78	28	21	24	2	1

TSDF = Treatment, storage, and disposal facility.

[a]Flux chamber shading was utilized in all sampling events following soil tilling after surface application of the waste in order to evaluate the effect shading had on chamber air and soil temperatures. Tenax sorbent tubes were used to collect air emission samples. Samples were analyzed by gas chromatograph/flame ionization detector. Waste was a combination of American Petroleum Institute separator sludge and dissolved air flotation sludge.

[b]Test duration was approximately 8 d.

[c]In some instances emissions are greater than amount applied. Although there are no clear reasons in the test report for these anomalies, oil in the soil prior to the application of waste for the test would contribute to the measured emissions and could account for part of the reported results.

[d]On the first day of tests, sampling location C was stepped in, which may have affected the results.

177 °C). Annual sludge disposed of ranges from about 5.4 to 9.1 x 10^6 kg/yr, and a typical application rate is about 16 L/m^2 (50 bbl/1/8 acre).

The objectives of the test program at the Site 20 land treatment facility included the following:

- To determine the amount of organics volatilized relative to the applied purgeable organics and of the applied oil
- To estimate the emissions of applied VO from the test plots for the 5-week testing period and annually for the entire land treatment facility
- To determine the effectiveness of subsurface injection in reducing VO emissions from land treatment by comparing the measured emission rates from the two application methods
- To determine the extent of oil degradation and/or measurable biological activity
- To determine the effects of various environmental and operational parameters on emission rates and emission rate measurements, including those due to the emission measurement procedure
- To compare the measured emission rates to those calculated using the Thibodeaux-Hwang air emission model.

Three adjacent plots were selected for the emission tests; each plot was 27.7 m long and 15.2 m wide. A portion of the land treatment area was recovering from oil overloading, but the test plots were selected in an area that had not experienced oil overloading. The center plot of the three was used as a "control plot," i.e., no waste was applied, and sludge was applied to the other two test plots using normal refinery procedures. Each plot was tilled two to three times per week (in addition to tilling immediately following sludge application) during the test period. (This was the typical practice at this refinery.) The waste loading was 1.40 x 10^4 kg of sludge per plot.

Two flux chambers were used simultaneously throughout the testing program to measure emissions. Eight measurements were made daily on each test plot and two on the control plot. Each plot was marked into 21 grids. Both random and semicontinuous sampling techniques were employed. Of the eight measurements made on each test plot, four measurements were made on

random grids, while the remaining four measurements were made (two each) on two control grids. This procedure was designed to reduce both random and systematic error associated with the estimate of the mean emission rate. In addition to the flux chamber sampling of air emissions, numerous other parameters were analyzed.

Sampling was performed for 4 days during three separate sampling periods that were approximately 7 to 10 days apart. Testing began October 9, 1984, and concluded on November 2, 1984. During this time, tilling occurred approximately three times per week for a total of 16 episodes.

Canister air samples, sludge samples, and liquid samples were analyzed by GC-FID/PID/HECD. The determination of water, oil, and solids content in the sludge was done according to the tetrahydrofuran (THF) protocol supplied by the land treatment operator. The percent of oil and grease in soil grab samples was determined by EPA Method 413.1.[53] Soil physical properties were determined by standard methods from undisturbed soil cores. Results of an analysis of a single sludge sample by the THF method showed 71.6 percent water, 19.8 percent oil, and 8.6 percent solids. Figure F-6 shows the trend over the first 12 days in half-day average emission flux rates of total VO as calculated from the combined Byron (onsite, syringe samples) and Varian (offsite, canister samples) GC analytical results. Table F-54 shows estimated total cumulative emissions of selected individual compounds and total VO over the entire test schedule.

F.1.4.5 Site 15.[55] From November 14 through November 17, 1983, field tests of land treatment emissions were conducted at Site 15, a commercial waste disposal operation that services four industrial clients exclusively. The site is located in the Gulf Coast area and includes both a land treatment area and a landfill. Tests of landfill emissions are discussed in Section F.1.3.3. Waste in the form of an oil-water emulsion is disposed of as it is received because there is no onsite storage. Liquid waste is received via tank truck and discharged through flexible hose onto the surface (at ambient temperature) and spread with a toothed harrow (teeth up). For the field test, the dimensions of the application area were nominally 30 m by 18.3 m.

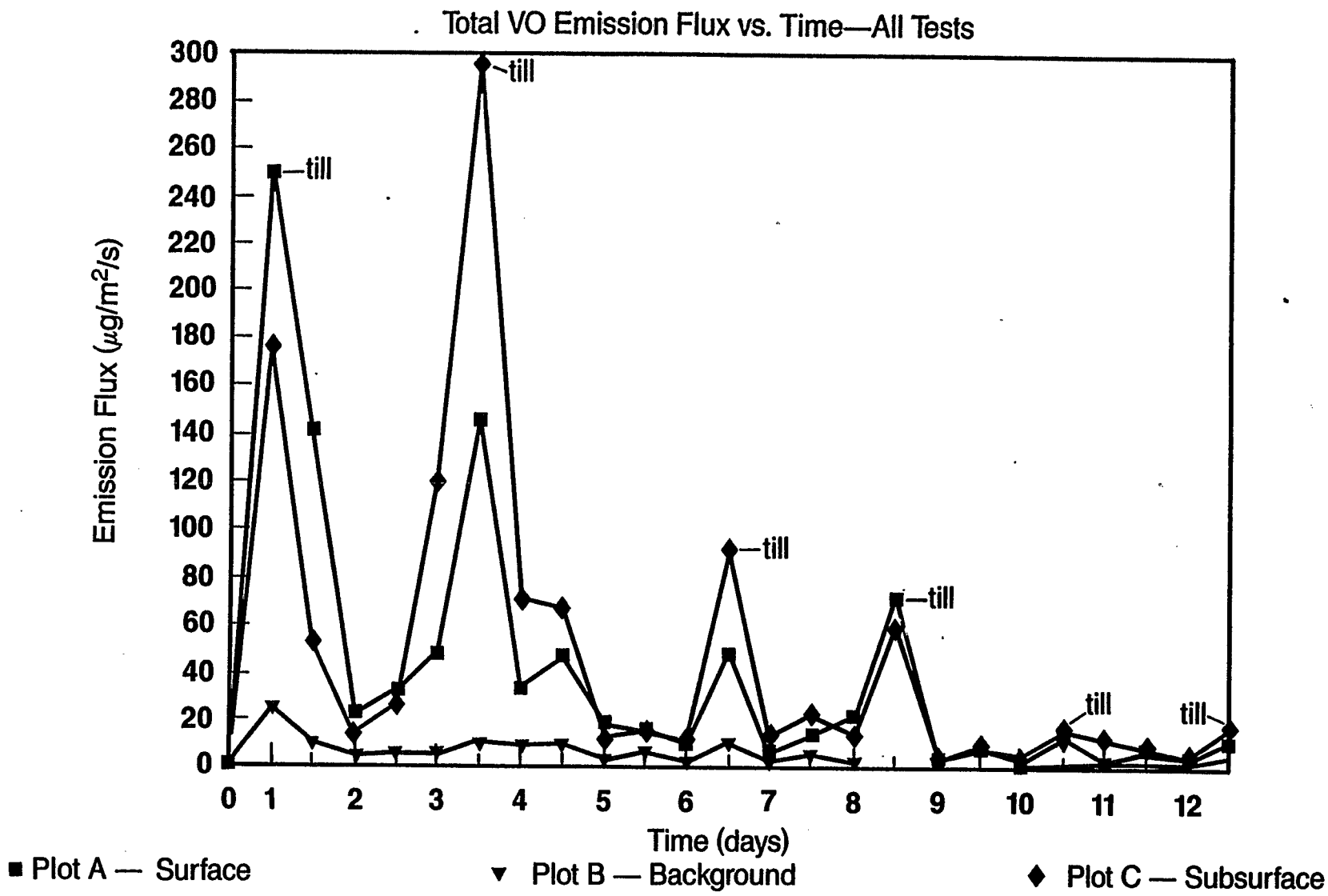

Figure F-6. Measured VO emission flux for first 12 days at Site 20.

TABLE F-54. ESTIMATED CUMULATIVE EMISSIONS OF SELECTED ORGANIC CONSTITUENTS AND TOTAL VO FROM CRUDE OIL REFINERY WASTE LAND TREATMENT FIELD TESTS AT TSDF SITE 20[54]

Constituent[a]	Cumulative emissions,[b] wt % of applied material[c]	
	Surface application	Subsurface injection
n-Heptane	60	94
Methylcyclohexane	61	88
3-Methyl-heptane	52	77
n-Nonane	56	80
1-Methylcyclohexene	49	76
1-Octene	50	74
β-Pinene	17	21
Limonene	22	26
Toluene	37	56
p-, m-Xylene	35	48
1,3,5-Trimethylbenzene	21	27
o-Ethyl-toluene	32	42
Total VO[d]	30	36
Total oil	1.2	1.4

TSDF = Treatment, storage, and disposal facility.
VO = Volatile organics.

[a]Air samples for chemical specification were collected in canisters using a flux chamber.

[b]Test duration was 5 weeks.

[c]Waste oil consists of 50 to 75 percent dissolved air flotation/American Petroleum Institute (API) float, 20 to 30 percent API separator cleanings, and about 5 percent miscellaneous oily wastes.

[d]Determined using a purge-and-trap technique and analyzed using a Varian Model 3700 GC-FID/PID/HECD.

A single truckload of waste totaling 20,060 L was offloaded during the testing period. The calculated application rate was 34,720 g/m^2; however, observations indicated the waste was not spread evenly, and daily tilling did not appear to even out the waste during testing. In addition, the waste was reported to have been aged for about 1 year. Table F-55 lists waste and land application characteristics.

The objective of the test program at the Site 15 land treatment plot was to provide data to evaluate both measurement and modeling techniques for determining air emissions from hazardous waste land treatment technologies. Because the test was conducted using aged waste, results are not expected to be representative of the level of air emissions from other land treatment operations.

For measurement purposes, the surface of the land treatment plot was divided into six equal grids. Air emission measurements were made over a 3-day period using the flux chamber technique. Flux chamber sampling locations were selected at random, with the control point providing a common position for sampling each day. Canister samples were collected from two grids in addition to the control point. Soil samples also were collected from two grids in addition to the control point, though only two of the soil samples (control point and grid 5) corresponded to flux chamber measurements. Gas and soil sample analysis was done offsite using a Varian Model 3700 GC-FID/PID/HECD. Figure F-7 presents the emission flux rates over time as calculated from the flux chamber measurements. Table F-56 shows cumulative measured total VO emissions and cumulative benzene emissions.

F.1.4.6 Site 21.[58] Over a period of 7 months in 1983, an independent research organization conducted a laboratory study of land treatment emissions by setting up a laboratory simulation of the land treatment of oily refinery sludges. The simulation used both soil and sludges from refineries that use land treatment routinely to dispose of their hazardous waste.

The objectives of the study were to:

- Obtain detailed information and samples of sludges and soils from refineries that use land treatment to dispose of oily sludges

TABLE F-55. TSDF SITE 15 WASTE AND LAND TREATMENT FACILITY[a] CHARACTERISTICS[56]

Characteristic	Measure
Area of land treatment site (m^2)	520
Waste volume applied (L)	20,060
Oil in waste (wt %)	23.4
Average density of applied waste (g/cm^3)	0.9
Average depth of oil penetration (cm)	19.6
Approximate elapsed time from waste application	
First tilling (h)	19
Second tilling (h)	47

TSDF = Treatment, storage, and disposal facility.

[a]Site 15 is a commercial waste disposal operation that services four industrial clients exclusively. During the testing period at the land treatment site, a single truckload of waste with the characteristics listed was offloaded.

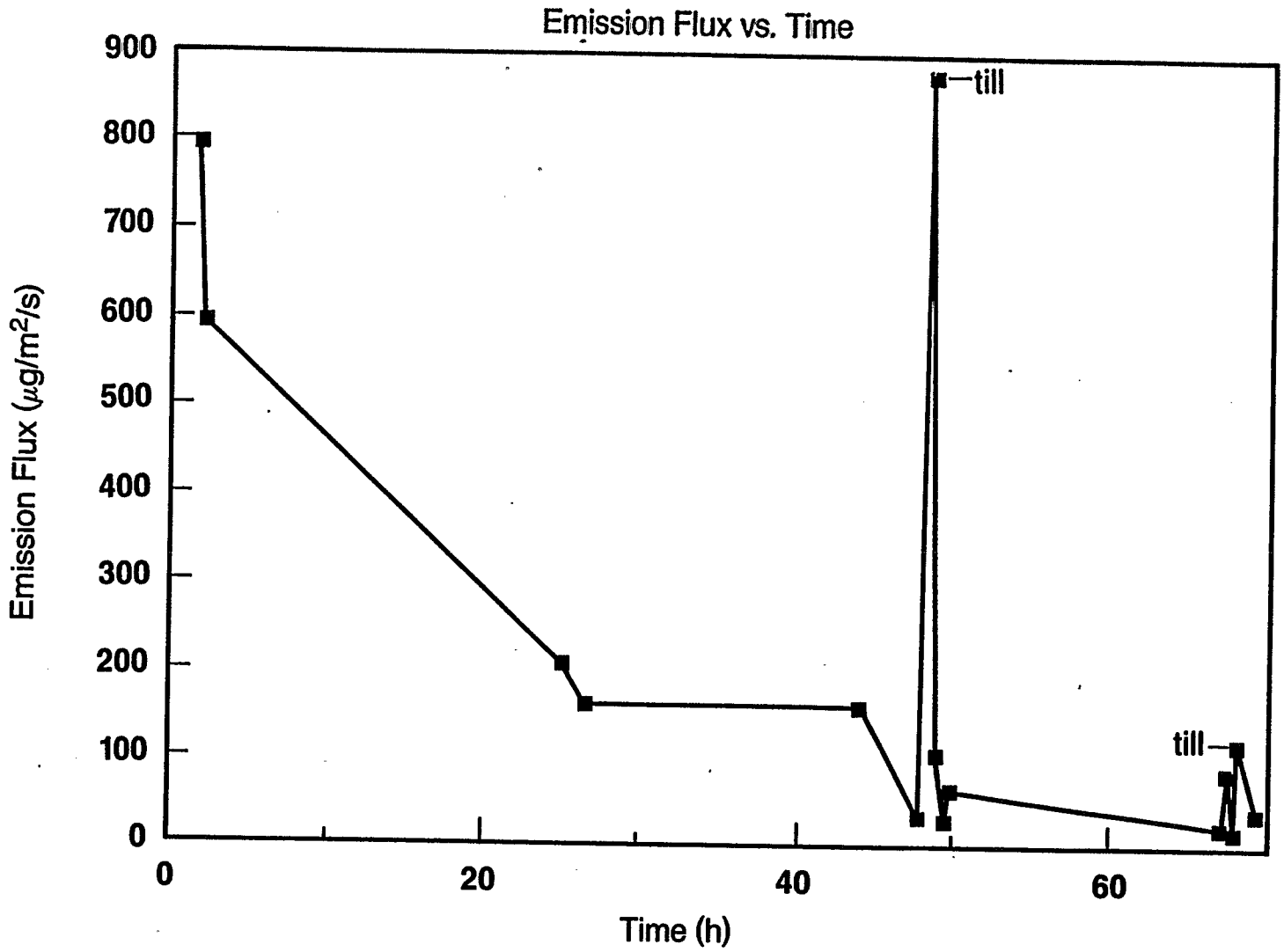

Figure F-7. Measured emission flux at Site 15.

TABLE F-56. MEASURED CUMULATIVE LAND TREATMENT EMISSIONS[a] AT TSDF SITE 15[57]

Constituent	Elapsed time, h	Measured emissions,[b] wt %
Total VO[c]	69	0.77 (wt % of applied oil)
Benzene	69	3.9 (wt % of applied benzene)

TSDF = Treatment, storage, and disposal facility.
VO = Volatile organics.

[a]Air emissions sampled with a flux chamber.

[b]Test was conducted using surface-applied waste reported to have been aged about 1 year. As a result, the volatiles are expected to have been emitted to the atmosphere prior to the test.

[c]Determined using purge-and-trap technique and analyzed using a Varian Model 3700 gas chromatograph-flame ionization detector/photoionization detector/Hall electrolytic conductivity detector.

- Characterize sludge and soil samples by both chemical and physical properties
- Identify sludge and soil samples that represent a broad range of typical land treatment operations
- Measure volatility during an 8-hour test using different combinations of sludge and soil types in controlled laboratory simulations of land treatment operations.

Actual soil and sludge samples were obtained from eight refineries. Soil samples were analyzed to determine pH (Method 21 from Agriculture Handbook No. 60),[59] specific gravity (ASTM D854-54),[60] moisture content (using weight loss after 16 h at 50 °C), particle size distribution (ASTM D422),[61] soil classification (ASTM D2487),[62] oil and grease content (EPA Method No. 413.1), organic carbon by heating (ASTM D2974),[63] and organic carbon by titration. Sludge samples were analyzed to determine oil, water, and solids content (by centrifugation), oil and grease content (EPA Methods 413.1 and 413.2),[64] and volatility (using procedures developed in an earlier phase of study).

The results of the soil and sludge analyses were used to select three soils and three sludges to represent a wide range of field conditions. Soils were selected to represent sand, silt, and clay soil types and sludges were selected to represent high, medium, and low volatility sludges. A series of tests was conducted using different combinations of the selected soils and sludge samples. The tests were conducted in enclosed soil boxes with a surface area of 0.093 m^2. Oil loading of the soil was varied over a wide range in the tests.

During each test, THC emissions were monitored continuously using a Byron 401 analyzer. During each test, air flow over the soil box, humidity, soil and air temperatures, and background levels of hydrocarbons were periodically monitored and regulated as necessary.

Figure F-8 presents the average emission flux rate for all tests over time. These values were calculated in a separate study[65] from the test report. The average cumulative emissions over time for all tests that were run for the entire 8-hour test period are presented in Table F-57.

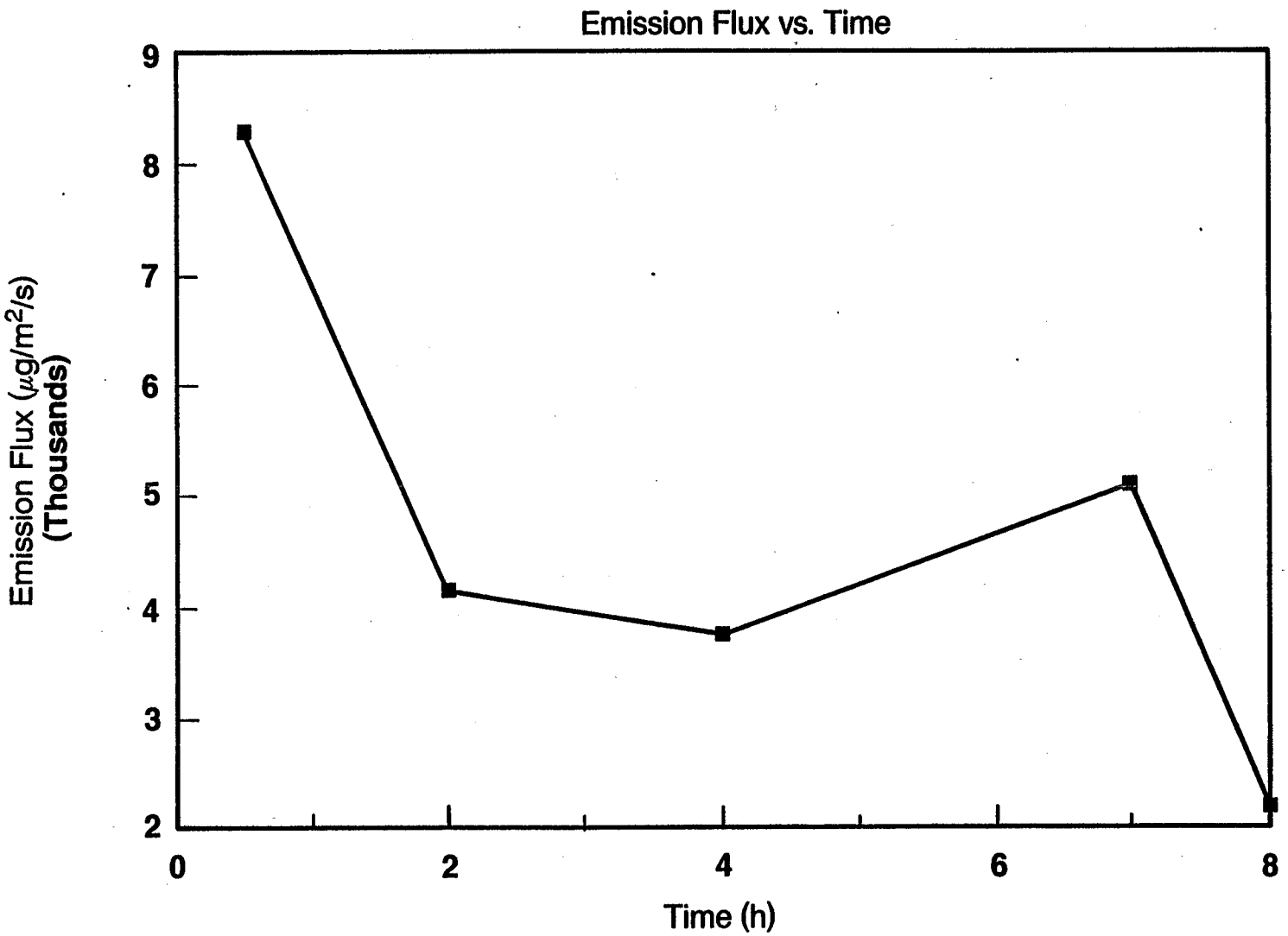

Figure F-8. Average measured emission flux at Site 21.

TABLE F-57. AVERAGE CUMULATIVE EMISSIONS FROM A LABORATORY SIMULATION OF PETROLEUM REFINERY WASTE LAND TREATMENT[a] AT SITE 21[66]

Run number	Type of waste[b]	Cumulative emissions,[c] wt % of applied oil
18	SL-14	9.1
21	SL-11	4.4
24	SL-14	0.02
27	SL-11	0.6
28	SL-14	0.1
32	SL-11	3.0
33	SL-11	2.6
34	SL-14	0.01
35	SL-12	0.9
36	SL-11	78.8
37	SL-14	9.9
40	SL-12	0.7
41	SL-11	2.8
44	SL-13	4.9
45	SL-13	49.9
46	SL-13	7.7
47	SL-13	6.9
48	SL-13	5.0
49	SL-13	9.7
50	SL-13	1.1
51	SL-13	0.47

[a]Independent research Laboratory simulation of land treatment activities. Total hydrocarbon emissions monitored using a Byron 401 analyzer.

[b]Sludge type (surface applied):

SL-11 = Emulsions from wastewater holding pond
SL-12 = Dissolved air flotation (DAF) sludge
SL-13 = Mixture of American Petroleum Institute (API) separator bottoms, DAF froth, and biological oxidation sludge
SL-14 = API separator sludge.

[c]Test duration for each run was 8 h.

F.1.4.7 Site 22.[67] In 1979, field tests were conducted at a land treatment facility at Site 22, a Midwestern petroleum refinery. The refinery had a capacity of 19.7 million L/d (124,000 bbl/d) and produced a typical fuels product mix.

In the spring of 1976, three 2.4 m by 46 m test plots, designated A, B, and C, were laid out side by side on a flat grassy area near a tank farm on refinery property. During 1976, 1977, and 1978, the plots were used for land treating oily refinery wastes. Over this 3-year period, Plot A received a centrifuge sludge and Plot B an API separator sludge. Plot C was used as a control and received no waste applications. The final waste applications were carried out on November 10 and 14, 1978, on Plots A and B, respectively, and the final tilling on December 4. All three plots were rototilled on May 10, 1979, in preparation for the emission study that began May 22. Tests were concluded October 9, 1979.

The objective of the field tests conducted at Site 22 was to attempt to quantify VO emissions from the land treatment of two refinery wastes (API separator sludge and a centrifuge sludge). The API separator sludge was applied at a rate of 29.9 L/m^2 (760 bbl/acre) and contained 1.7 kg/m^2 (15,000 lb/acre [5.2 weight percent]) organic fraction. Centrifuge sludge from a refinery sludge and wastewater treatment dewatering operation was applied at a rate of 35.4 L/m^2 (900 bbl/acre) and contained 3.2 kg/m^2 (28,300 lb/acre [8.1 weight percent]) organic fraction. Table F-58 summarizes the waste loading on Plots A and B of the test site and presents properties of the applied sludges.

The API separator sludge was obtained from the primary WWT separators, sampled, and, prior to being applied to the test plot, was weathered for 14 days in open 18.9-L buckets in an outdoor open shelter. The centrifuge sludge was derived from centrifuge dewatering of an oily sludge mix stemming from normal refinery operations and wastewater treating, including the API separator sludge.

The sludges were analyzed using a modified extraction technique for phase separation to determine the amount of organics, water, and minerals in the sludge. However, because of the temperatures involved, some loss of light organics may have occurred. Soil sampling was attempted, but difficulties with obtaining a representative soil sample and uneven waste spreading made organic balance determinations of little significance.

TABLE F-58. WASTE CHARACTERISTICS AND APPLICATION RATES FOR FIELD EXPERIMENTS ON PETROLEUM REFINERY WASTE LAND TREATMENT, TSDF SITE 22[68]

Test information	Test location A	Test location B
Sludge type	Centrifuge sludge	API separator sludge
Total sludge applied (kg/m^2)	39.0	33.0
Total oil applied (kg/m^2)	3.2	1.7
Incorporation depth (cm)	20.3	20.3
Final oil concentration in soil (wt %)	4.3	3.0
Sludge composition[a]		
Oil (wt %)	8.1	5.2
Water	72.1	85.2
Solids	19.8	9.6

TSDF = Treatment, storage, and disposal facility.
API = American Petroleum Institute.

[a]Analyzed using a modified extraction technique for phase separation. Because of temperature involved, some loss of light organics may have occurred.

A flux chamber with a surface area of 0.093 m^2 was inverted over the area of the test plot to be studied and served to collect total emissions from the plot soil beneath it. The box was continuously purged with a stream of fresh air that was carried from the box through sample lines into an adjacent trailer where a Mine Safety Appliances Company Model 11-2 continuous hydrocarbon/methane analyzer was used to measure VO as methane and total NMHC. There was no identification of specific organic emissions.

The experimental program was carried out in three phases:

- Phase I - Background Tests 1, 2, and 3 on the three test locations.
- Phase II - Emission Tests 4, 5, and 6 on the centrifuge sludge applied to test location A.
  - -- Test 4 data were not included.
  - -- Test 5 was conducted at a new location with new waste applied.
  - -- Test 6 followed rototilling at the end of run 5 on the same ground area.
- Phase III - Emission Tests 7, 8, and 9 on the API separator sludge applied to test location B.
  - -- Test 7 was conducted at a new location with new waste applied.
  - -- Test 8 was conducted at a new location with new waste applied.
  - -- Test 9 followed rototilling at the end of run 8 on the same ground area.

Table F-59 summarizes the Site 22 data providing the fraction of applied oil emitted during the test. These results were calculated using the measured emission flux rates and the amount of oil applied during waste application. Figure F-9 shows derived tabular values of total VO emission flux versus time at Site 22.

F.1.5 Transfer, Storage, and Handling Operations

F.1.5.1 Site 6.[70] Site 6 is a commercial hazardous waste TSDF. The site began operation in 1972 and was acquired by the current owner in 1979 and upgraded to accept hazardous wastes. Before a waste is accepted for

TABLE F-59. FRACTION OF APPLIED OIL EMITTED BY LAND TREATMENT TEST, AT TSDF SITE 22[69]

Waste type	Test No.[a]	Test duration, d/h	Wt % of applied oil emitted
Centrifuge sludge	5	0.83/19.9	0.1
	6	12.8/307	1.8
API separator sludge[b]	7	25.8/619	10.9
	8	5.1/122	3.3
	9	21.7/520	10.4

TSDF = Treatment, storage, and disposal facility.
API = American Petroleum Institute.

[a]Air emissions sampled with flux chamber. Waste was surface-applied.

[b]Weathered for 14 d in open 18.9-L buckets in an outdoor open shelter prior to application.

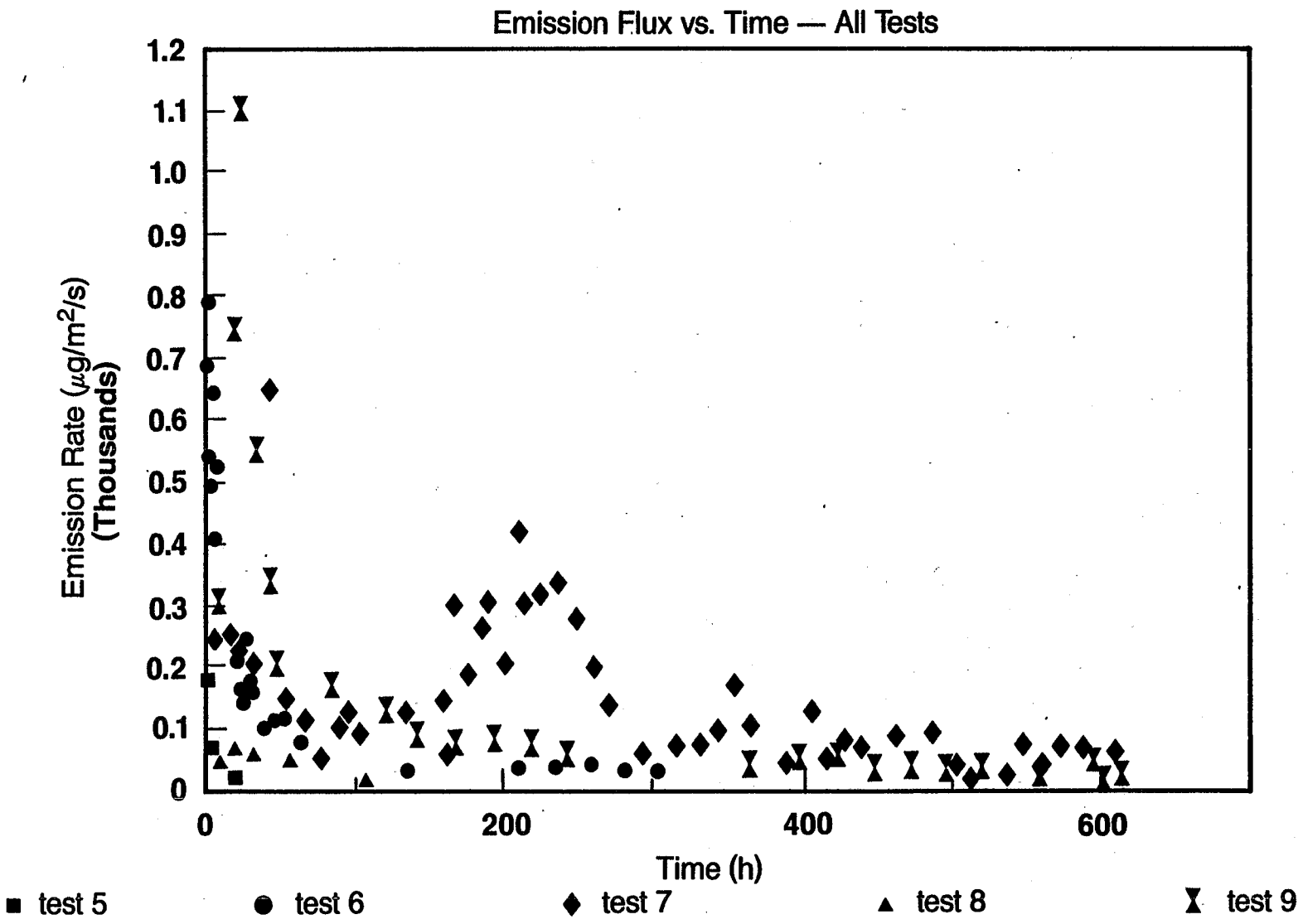

Figure F-9. Measured emission flux for tests at Site 22.

disposal at the facility, samples must be analyzed to determine compatibility with the facility processes. Water-reactive, explosive, radioactive, or pathogenic wastes are not accepted. Hazardous wastes are received from the petroleum, agricultural products, electronics, wood and paper, and chemical industries.

All wastes that are stored at the facility are received in bulk 0.21-m^3 drums, 18.9-L pails, or carboys. Wastes are stored in drums or tanks. Typical wastes stored at the facility include pesticides, PCB, wood preservatives, and miscellaneous organics.

The drum marshalling area is situated near the waste processing area. Bermed embankments surround the staging area. All drums are offloaded into this area. Here, they are opened and sampled to determine the proper processing. The drums containing free liquids are then selected for decanting. Pumpable organics are sent to the surge tanks and separation tanks for physical separation of phases. Chlorinated organics are solidified and then landfilled. Supplemental fuels are sent to the fuel tanks for storage and testing prior to being hauled offsite. Nonchlorinated, nonignitible aqueous organic wastes are sent to the aqueous organic tank. Sludges from the decanting operation are solidified with the non-RCRA kiln dust and landfilled. During the site visit, the drum handling area contained 220 open drums. Turnaround time for the drum handling area is approximately 3 days.

The objective of the drum storage and handling area testing was to survey ambient concentrations at and immediately downwind of the drum storage and handling area. Section F.1.1.6 discusses source testing of a Site 6 surface impoundment; Section F.1.3.2 describes the emission measurements made on inactive and active Site 6 landfills.

A survey was made during the morning of June 22, 1984, of the various drum storage areas, including the tank storage area, an outside drum storage area, a building for PCB drum storage, and a drum transfer area. During the survey, no specific activity was taking place in the area. Ambient hydrocarbon measurements were made in the immediate vicinity of the storage areas using a portable OVA. Table F-60 presents the results of the survey.

TABLE F-60. SUMMARY OF DRUM STORAGE AND HANDLING AREA SURVEY OF AMBIENT HYDROCARBON CONCENTRATIONS,[a] SITE 6[71]

Sampling location	Concentration of THC, ppm	Comments
Vicinity of tank storage	0.2	220 empty drums; all open; in good condition
Drum storage area	0.0	600 empty drums; all open; in good condition
Drum transfer area	0.0	No decantation in progress
PCB building	0.1	70 drums; 32 empty; all in good condition

THC = Total hydrocarbon.
PCB = Polychlorinated biphenyl.

[a]Ambient hydrocarbon measurements were made in the immediate vicinity of the storage areas with a portable organic vapor analyzer.

F.1.5.2 Site 23.[72,73] Site 23 is a commercial chemical conversions and reclaiming facility located in the eastern United States. Solvents are recycled at the facility.

The objectives of the testing program at Site 23 were to develop and verify techniques for determining air emissions from drum storage areas and storage tanks. The field testing was conducted during the week of October 24, 1983.

A large number of drums were located in the various drum storage areas at Site 23. Site personnel provided a drum inventory taken in July 1982. The total inventory of drums amounted to almost 28,000, with approximately 3,000 of those being empty, used drums. Test personnel did not do a complete drum inventory during the test period, but they estimated that the number of drums in storage in three areas was approximately 35 percent less than had been inventoried in July 1982. Additionally, the number of empty, used drums in storage appeared to be significantly less than the 3,000 inventoried by plant personnel.

The drums in the three major storage areas were, for the most part, stacked four drums high. One of the areas was partially submerged in approximately 0.3 to 0.6 m of water. This area served as an emergency retention area during periods of excessive rainfall and was enclosed with an earthen dike. None of the drum storage areas was covered.

During the test period, several types of drum handling activities were being performed. The basic operations were:

- Emptying old drums filled with waste and distillation residues
- Removing the tops of empty, used drums in preparation for removing these drums from the plant site
- Emptying drums of spent solvent for purification
- Filling drums with the reclaimed solvent and/or bottoms from the solvent distillation/purification process.

Emissions were examined using real-time gas analyzers. The measurements were made at a distance of approximately 2.4 m from the drums on all four sides of the drum pile. The wind during this examination was from the

southwest and had a speed of 1.2 km/h. Between the two drum storage areas was a drum transfer area that contained a number of open drums. This area contributed to the emissions measured on the adjoining sides of the two storage areas. The measured gas concentrations are presented in Table F-61.

Storage tanks at Site 23 range in size from 1,290 to 71,900 L. Feedstocks, products, and wastes are all stored in aboveground tanks. In addition, three underground storage tanks are used to store boiler fuel. All of the tanks are vented directly to the atmosphere. Pressure-relief valves are not present in the vent lines.

Sampling was attempted on five storage tank vents. The sampling equipment consisted of a hot wire anemometer for velocity measurements and a variety of gas monitoring/collection devices. Portable FID and/or PID analyzers were used to obtain real-time continuous total hydrocarbon concentration measurements in excess of 10,000 ppmv at the exits of these vents. When the hot wire anemometer proved to be insufficiently sensitive, a dry-gas meter and a 10-mL bubble meter were used to measure gas flows. These meters also failed to register any gas flows, so no further examination of vent emissions was undertaken.

F.1.5.3 Site 7.[75] Site 7 is a commercial hazardous waste management facility located in the northeastern United States. The site was developed for hazardous waste operations in the early 1970s. Source testing was conducted at a drum storage building during the first week of October 1983. Section F.1.1.7 discusses source testing on three surface impoundments in the Site 7 WWT system and Section F.1.3.5 presents source testing results from Site 7 active and closed landfills.

Drum storage at Site 7 takes place in two buildings. One building is used for storage of drums containing PCB, and another building (different location) houses hazardous and nonhazardous drums. Field measurements were made at the hazardous and nonhazardous drum storage building only. The building dimensions are nominally 33.5 by 48.8 by 4.9 m, with a 12:1 roof slope. The building is ventilated by two manually operated fans nominally rated at 0.75 kW (1 hp)--5.8 m^3/s at 0.245 standard pressure (S.P.). Makeup air enters through two vents at the end of the building opposite the

TABLE F-61. RESULTS OF EMISSION SURVEY[a] AT DRUM STORAGE AREA, SITE 23[74]

Sampling location	Distance of measurement from drums, m	Concentration of THC, ppm	
		OVA	PID
Upper drum storage area			
East side	0.3	60	9
East side	6.1	7	0.5
South side	2.4	5	0.1
West side	2.4	5-7	0.1
North side	1.5	10-20	5-10
Lower drum storage area			
East side	2.4	10-20	0-2
South side	2.4	20-30	5-15
West side	2.4	5	0.1
North side	2.4	7	0-0.2

THC = Total hydrocarbon.
OVA = Organic vapor analyzer.
PID = Photoionization detector.

[a]Real-time gas analyzer measurements were made on all four sides of the drum pile. The wind was from the southwest at 1.2 km/h. A drum transfer area containing a number of open drums between the two drum storage areas contributed to the emissions measured on the adjoining sides of the two storage areas.

fans and through a 27.4-m roof vent. The design ventilation rate for the drum storage building and adjoining office is six air changes per hour. Four emergency fans nominally rated at 1.1 kW (1-1/2 hp)--6.9 m^3/s at 0.286 S.P.--are available. An explosive-level monitor provides an alarm warning at 35 percent and activates the emergency fans at 60 percent.

The drum storage building is designed to process 1,000 drums/day. This translates to 10 to 11 trucks/day. Total design storage capacity is 2,000 drums. Drums are filled, labeled, sealed, inventoried, and stored in cordoned areas by material type. The stored drums typically are comprised of 40 to 50 percent landfill waste, 35 to 50 percent fuels, 1 to 5 percent chlorinated solvents for recycling, 5 to 10 percent aqueous waste, and 1 percent other. During the field test, it was estimated that the storage area had 1,500 drums. The drum types included 95 percent standard 0.16-m^3 steel drums, 2 to 5 percent overpack, and 1 percent 0.11-m^3 fiber drums. No leakage was observed.

The objective of the tests on the drum storage building was to develop and verify techniques for determining air emissions from drum storage facilities. A vent was fabricated at the exit of the ventilation fans. Velocity traverses and real-time THC measurements were made at a total of 48 points within the vent. The hydrocarbon measurements were all 4 ppmv by OVA and 0 ppmv by PID. In addition, a single canister sample was collected from the exhaust air and analyzed offsite using a Varian Model 3700 GC-FID/PID/HECD. The emission rate from the vent was calculated as the product of the concentration and flow rate. Table F-62 lists the measured emission rates.

F.2 TEST DATA ON CONTROLS

The controls considered for TSDF emission sources serve either to suppress air emissions by capture, containment, or destruction of VO (e.g., by using enclosures or covers for surface impoundments and tanks or combustion devices for vents) or to remove VO from hazardous waste streams (e.g., by steam stripping or distillation) to avert air emissions from downstream treatment or disposal operations. This section presents the results of field tests conducted to evaluate the efficiency of controls to suppress air emissions or remove VO from hazardous waste streams.

TABLE F-62. SOURCE TESTING RESULTS[a] FOR TSDF SITE 7 DRUM STORAGE BUILDING[76]

Constituent	Emission rate, x 10^6 Mg/yr
Toluene	2,300
Total xylene	1,000
Naphthalene	560
Methylene chloride	80,000
1,1,1-Trichloroethane	4,500
Carbon tetrachloride	3,500
Tetrachloroethylene	45,000
Total NMHC[b]	150,000

TSDF = Treatment, storage, and disposal facility.
NMHC = Nonmethane hydrocarbon.

[a]Vent emission rate calculated as the product of the concentration and flow rate. Concentration determined from a single canister sample of the exhaust air and flow rate determined from velocity traverses made at a total of 48 points within the vent.

[b]The NMHC total does not represent a column sum because only major constituents (in terms of relative concentrations) are presented.

F.2.1 Capture and Containment

F.2.1.1 Air-Supported Structures--Site 12.[77] Section F.1.2.5 contains a description of the testing program conducted during the week of August 13 through 19, 1984, at the Site 12 WWT system. One of the objectives of the testing program was to measure the control efficiency of the dome and carbon adsorption system designed to control odors and emissions from the aerated lagoon serving as part of the activated sludge system.

The control effectiveness of the dome structure is a measure of the dome's ability to contain gas-phase NMHC emissions from the aerated lagoon. During the test, the control effectiveness could not be quantified. The plant indicated the dome had a relatively good seal and estimated the total leakage at 0.14 m^3/s. Test personnel performed a crude leak check of the dome by surveying the perimeter with a portable hydrocarbon analyzer. The measured total hydrocarbon concentration ranged from 2 to 3 ppmv near the carbon adsorber to 30 to 40 ppm at the escape hatch. Personnel also used water to roughly quantify any detected leak by spraying the liquid along the dome seal and observing any bubbles. Relatively few small leaks were found, indicating that the leak rate may be much less than 0.14 m^3/s.

F.2.2 Add-on Control Devices

F.2.2.1 Gas-Phase Carbon Adsorption.

F.2.2.1.1 Site 24.[78] A test program was conducted for 4 days during May 1985 on the air-stripping system used to treat leachate at Site 24. Site 24 is on the National Priority List (NPL--Superfund) currently managed by EPA under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). One of the objectives of the test program was to assess the performance of the existing gas-phase, fixed-bed carbon adsorption system used to treat the air effluent from the air stripper. The air-stripping process is described in Section F.2.3.2.1.

Air samples of the stripper exhaust and carbon adsorber exhaust were taken at a variety of water and air flow rates. No information was documented concerning sampling equipment, but sample analysis was performed using GC-MS. Process data collected included all stripper influent and effluent temperatures and both air and water influent rates to the air stripper.

Material balances and stream flow and concentration data were used to characterize the carbon adsorber system influent and effluent. Air measurements were taken under the test conditions yielding the highest VO removal from the water. This was obtained when the influent water rate was throttled down to 1,140 kg/h, and the air flow correspondingly increased to 4.8 m^3/min, giving the highest air:water ratio observed during testing. Table F-63 presents the source testing results.

F.2.2.1.2 Site 12.[79] Section F.1.2.5 contains a description of the WWT system at Site 12, including the activated carbon fixed beds used to treat the off-gases from the aerated lagoon and the carbon canisters used to control breathing and working losses from the neutralizer tanks.

To measure the effectiveness of the gas-phase fixed-bed carbon adsorption control devices, the inlet to and exhaust from the carbon adsorption system and the inlet to and exhaust from the disposable carbon drums were sampled during the week of August 13 through 19, 1984.

Gas volumetric flow rate was determined by procedures described in EPA Reference Method 2. Average gas velocity was determined following procedures outlined in EPA Reference Method 1. Gas samples were collected from the carbon adsorption system inlet and outlet two to three times daily in evacuated gas canisters. Evacuated gas canisters fitted with flow controllers were used to collect the carbon drum inlet and outlet samples integrated over a 16-h period. Offsite analyses of these samples permitted calculation of the removal efficiency of each vent emission control device. In addition, a small canister of clean, activated charcoal was placed in line upstream bypassing each 0.21-m^3 (55-gal) drum to collect all VO being vented over a known time interval. The carbon was extracted offsite to yield the mass/unit time of VO reaching the control devices. This information was combined with the removal efficiency data to allow calculation of the average emissions to the atmosphere from each control device as well as the efficiency of the carbon drums. Offsite analyses of air samples were performed on a Varian Model 3700 GC-FID/PID/HECD. Table F-64 presents the carbon adsorption fixed-bed system removal efficiency for specific species. Table F-65 presents the neutralizer vent carbon drum removal efficiency results.

TABLE F-63. SOURCE TESTING RESULTS[a] FOR TSDF SITE 24, AIR STRIPPER EMISSIONS WITH GAS-PHASE, FIXED-BED CARBON ADSORPTION SYSTEM APPLIED

Constituent	Exhaust from air stripper		Exhaust from carbon adsorber		Carbon adsorber system organic removal efficiency, wt. %
	Mass flow rate, x 10^3 kg/h	Conc., ng/L	Mass flow rate, x 10^6 kg/h	Conc., ng/L	
1,2,3-Trichloropropane	13	44,000	0.14	<1.0	99.999
(o,m)-Xylene	5.2	18,000	2.6	9.0	99.95
p-Xylene	1.7	6,000	1.7	5.7	99.9
Toluene	2.8	9,800	1.6	6.0	99.9
Aniline	NA	NA	NA	NA	NA
Phenol	NA	NA	NA	NA	NA
2-Methylphenol	NA	NA	NA	NA	NA
4-Methylphenol	NA	NA	NA	NA	NA
Ethylbenzene	0.75	2,600	0.43	1.5	99.9
1,2-Dichlorobenzene	0.097	340[b]	0.14	<1.0[b,c]	99.9
1,2,4-Trichlorobenzene	NA	NA	NA	NA	
Other VO[d]	0.48	1,700	0.58	2.0	99.9
Total VO[e]	24	82,400	7.3	25.0	99.97

TSDF = Treatment, storage, and disposal facility.
NA = Not available.
VO = Volatile organics.

[a]This tables demonstrates the effectiveness of activated carbon as an adsorbent for VO in gas streams.

[b]Concentration reported for all isomers of dichlorobenzene, not just 1,2-dichlorobenzene.

[c]Constituent concentration below detection limit.

[d]Includes 4-methyl-2-pentanone, chlorobenzene, tetrachloroethylene, and dichlorocyclohexane isomers.

[e]Includes all speciated organics.

TABLE F-64. SOURCE TESTING RESULTS[a] FOR TSDF SITE 12, AERATED LAGOON EMISSIONS WITH GAS-PHASE CARBON ADSORPTION FIXED-BED SYSTEM APPLIED[80]

		Gas-phase concentration, ppmv											
Date	Location	$MeCl_2$	$C_2H_4Cl_2$	Dioxane	Benzene	Toluene	CBZ	DCBZ	Chloroform	Paraffin	Aromatic	Halogen	NMHC
18-Aug-84	Inlet	4.3	240	0.0	21.2	92.1	0.4	1.2	81.5	153	117	331	607
18-Aug-84	Outlet	2.1	355	0.0	24.8	54.1	8.8	0.1	34.0	167	89.8	409	698
Removal eff.[b] (%)		51.2	-47.9	NA	-17.0	41.3	-2,100	91.7	58.3	-9.2	23.2	-23.6	-15.0
17-Aug-84	Inlet	4.0	204	0.0	26.0	5.7	13.2	0.6	27.4	63.2	33.1	251	348
17-Aug-84	Outlet	4.2	205	0.0	22.8	7.5	13.3	0.8	25.9	49.8	32.2	251	334
Removal eff.[b] (%)		-5.0	-0.5	NA	12.3	-31.6	-0.8	-33.3	5.5	21.2	2.7	0.0	4.0
17-Aug-84	Inlet	5.1	172	0.0	4.5	5.1	3.6	0.5	16.4	10.4	11.2	200	200
17-Aug-84	Outlet	5.1	231	0.0	15.1	19.6	6.6	0.2	16.1	13.0	38.6	264	317
Removal eff.[b] (%)		0.0	-34.3	NA	-236	-284	-83.3	60.0	1.8	-25.0	-245	-32.0	-42.8
17-Jul-84	Inlet	0.0	770	0.0	2.4	181	76.8	NA	NA	45.6	303	848	1,360
17-Jul-84	Outlet	0.0	770	0.0	2.6	119	112	NA	NA	50.3	217	1,070	1,480
Removal eff.[b] (%)		NA	0.0	NA	-8.3	34.3	-45.8	NA	NA	-10.3	28.4	-26.2	-8.8

TSDF = Treatment, storage, and disposal facility.
$C_2H_4Cl_2$ = 1,2-Dichloroethane.
DCBZ = Dichlorobenzene.
$MeCl_2$ = Methylene chloride.
NA = Not applicable.
NMHC = Nonmethane hydrocarbon.
CBZ = Chlorobenzene.
Paraffins = Primarily C7 and C8 compounds.
NMHC = Nonmethane hydrocarbon.

[a]This table demonstrates the variation in removal efficiency for gas-phase carbon adsorption of different specific compounds and chemical classes. The variation in removal efficiencies at different times and for different gas compositions is also given.

[b]The carbon beds were not removing the major species in the dome exhaust gas stream for two reasons. First, the beds were not originally designed for bulk removal of NMHC, but rather for odor control, specifically for removal of orthochlorophenol. Second, the extremely high (saturated) water vapor content in the exhaust gas stream interfered with the removal capabilities of the activated carbon.

TABLE F-65. SOURCE TESTING RESULTS[a] FOR TSDF SITE 12, NEUTRALIZER TANK EMISSIONS WITH A GAS-PHASE CARBON DRUM APPLIED, TSDF SITE 12[81]

		Gas-phase concentration, ppmv											
Date	Location	MeCl	$C_2H_4Cl_2$	Dioxane	Benzene	Toluene	CBZ	DCBZ	Chloroform	Paraffin	Aromatic	Halogen	NMHC
19-Aug-84	Inlet	0.0	17.9	0.0	12.4	12.4	0.5	0.0	0.1	8.7	25.1	19.3	53.1
19-Aug-84	Outlet	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.2	23.5	24.7
Removal eff.[b] (%)		NA	100	NA	100	100	100	NA	100	90.8	99.2	-21.8	53.5

TSDF = Treatment, storage, and disposal facility.
DCBZ = Dichlorobenzene.
NMHC = Nonmethane hydrocarbon.
NA = Not applicable.
CBZ = Chlorobenzene.
Paraffins = Primarily C7 and C8 compounds.

[a]This table demonstrates the variation in removal efficiency for gas-phase carbon adsorption of different specific compounds and chemical classes.

[b]The test report does not explain the negative removal efficiency for halogens.

As the results in Table F-64 indicate, the carbon beds were not removing the major species in the dome exhaust gas stream. This was not unexpected for at least two reasons. First, the beds were not originally designed for bulk removal of NMHC from the air stream. Rather, the beds were designed for odor control (for which they appeared to be effective) and specifically for removal of orthochlorophenol. Second, the extremely high (saturated) water vapor content in the exhaust gas stream interfered with the removal capabilities of the activated carbon. Generally, activated carbons are used only on gas streams with a relative humidity of 50 percent or less. The carbon drums were achieving a high degree of removal for specific components (i.e., 1-2 dichloroethane, benzene, toluene, chlorobenzene, and chloroform) and a relatively high degree of removal for specific compound groups (except halogens).

F.2.2.2 Liquid-Phase Carbon Adsorption--Site 5.[82] Tests were conducted on November 20, 1985, to evaluate the effectiveness of liquid-phase carbon adsorption used to treat steam-stripped wastewater at Site 5. Site 5 is a chemical manufacturing plant; the wastewater streams that are produced are predominantly water-soluble. The two major waste streams are redwater and whitewater. The waste streams pass through decanters where the oils are separated from the aqueous phase. A surface impoundment (lagoon) is used as a large storage vessel to provide a stable flow to the steam-stripping unit. The field testing of the Site 5 wastewater holding lagoon is described in Section F.1.1.5. The steam stripper removes organic compounds and water from the waste stream. Section F.2.3.1.3 describes the field testing of the steam stripper. The organics separate and are transferred to an organic slopsump. The water that separates from the steam-stripper condensate is recycled to the wastewater stream. Effluent from the steam stripper is passed through a liquid-phase carbon adsorption unit to recover any residual organics in the stream. The effluent is then pH-adjusted and discharged to surface water.

Sampling was conducted over a 2.5-h period with an average of four samples collected from each sampling point. Liquid grab samples were collected from the carbon adsorber influent and effluent streams in 40-mL VOA bottles. In addition, the temperatures of the influent and effluent

streams were measured. The VO in the liquid samples were speciated and quantified using a Varian Model 3700 GC-FID/PID/HECD. Material and energy balances and stream flow and concentration data were used to characterize the process streams around the carbon adsorption unit.

The flow rate of the stream leaving the carbon adsorption unit was 31,500 kg/h. The influent stream flow rate should have been virtually identical. Table F-66 presents the source testing results for the TSDF Site 5 liquid-phase carbon adsorption system.

F.2.2.3 Condensation.

F.2.2.3.1 Site 25.[83] Tests were performed on September 24 and 25, 1986, to evaluate the performance of the condenser system used to recover VO stripped from wastewater at Site 25. The system consisted of a water-cooled primary condenser, a decanter, and a water-cooled vent condenser. The steam stripping process is described in Section F.2.3.1.1.

The overhead vapors from the stripper pass through a condenser cooled with cooling tower water. The condensate enters a decanter that separates the heavier organic layer from water. The entire water layer is returned to the steam stripper, and the organic layer is drained periodically by the operator to a small collection tank for recycle back to the process. The collection tank is open-topped and has a layer of water and sludge floating on top of the organic layer.

The condenser is vented through the decanter to a vent condenser (cooled with cooling tower water). The vent condenser receives vapors from the initial water/organics/solids decanters and the steam stripper condenser/decanter. The initial decanters and storage tank are fixed-roof tanks and have conservation vents that open as necessary to prevent pressure buildup.

Samples of the vapor and liquid condensate condensed in the primary condenser were taken, and flow rates at these points were measured. The samples were analyzed by direct-injection GC after the compounds were identified using GC-MS.

Table F-67 presents the source testing results including mass flow rates of four specific volatile organics into and out of the Site 25 primary condenser. Condenser organic removal efficiencies are reported

TABLE F-66. SOURCE TESTING RESULTS[a] FOR TSDF SITE 5, STEAM STRIPPER WASTEWATER TREATED BY A LIQUID-PHASE CARBON ADSORPTION SYSTEM

Constituent	Influent to carbon adsorber		Effluent from carbon adsorber		Carbon adsorber organic removal efficiency,[b] wt %
	Mass flow rate, kg/h	Conc., ppmw	Mass flow rate, kg/h	Conc., ppmw	
Nitrobenzene	1.29	40	<0.025	<0.8	>98
2-Nitrotoluene	0.076	2.4	<0.025	<0.8	>67
4-Nitrotoluene	0.139	4.4	<0.025	<0.8	>82
Total	1.51[c]	47	<0.075[c]	<2.4	>95
Water	31,500[d]	NA	31,500[d]	NA	NA

TSDF = Treatment, storage, and disposal facility.
NA = Not applicable.

[a]This table presents the effectiveness of carbon adsorption as a wastewater treatment technology for dilute nitroaromatic-containing streams.

[b]Values represent minimum removal efficiencies resulting from constituent concentrations below analytical detection limits.

[c]Calculated as the total of the three detected compounds.

[d]Balance after accounting for three quantitated organics.

TABLE F-67. SOURCE TESTING RESULTS[a] FOR TSDF SITE 25, STEAM STRIPPER OVERHEAD TREATED BY PRIMARY WATER-COOLED CONDENSER[84]

Constituent	Mass flow rate, g/h			Condenser organic removal efficiency, %
	Vapor in[b]	Liquid out[c]	Vapor out	
Chloromethane	75.7	67.1	8.6	88.6
Methylene chloride	10,500	9,420	1,050	90.0
Chloroform	2,940	2,780	160	94.4
Carbon tetrachloride	136	122	14	89.6
Total VO[d]	13,700	12,400	1,230	90.9

TSDF = Treatment, storage, and disposal facility.
VO = Volatile organics.

[a]This table presents mass flow rates by constituent into and out of the primary water-cooled condenser associated with the steam stripper at TSDF Site 25. Under operating conditions at the time of the test, no additional removal was observed in the secondary condenser.

[b]From mass balance around stripper.

[c]By difference between inlet and outlet vapor flows.

[d]Total of four quantified organics.

based on effluent data. The condenser influent data presented are based on a mass balance.

F.2.2.3.2 Site 26.[85] Tests were performed on July 22 and 23, 1986, to evaluate the performance of the condenser system used to recover VO steam stripped from wastewater at the Site 26 plant. The system consisted of a primary condenser cooled with cooling tower water in series with a secondary condenser cooled with glycol. The steam-stripping process is described in Section F.2.3.1.2.

Samples of the condensate and vapor leaving the secondary condenser vent were analyzed, and the flow rates at each point were measured. The vapor flow rate (noncondensibles) leaving the condenser vent was measured by the tracer gas dilution technique with propane as the tracer because this is a closed system operated at a pressure of 28 kPa. Although the condenser was vented to an incinerator, these data were obtained to assess condenser vent rates because many steam strippers have the overhead stream vented to the atmosphere. The average condenser vent flow rate was 3.1 L/s reported at 101 kPa of pressure and 25 °C.

Condenser system efficiency was evaluated from the organic loading (organics entering the primary condenser with the vapor) and the quantity of organics leaving through the secondary condenser vent. The difference between the mass rates of organics entering with the feed and the mass rates of organics leaving the stripper with the bottoms represents the organic loading on the condenser. The 1,2-dichloroethane was by far the major organic constituent entering the condenser.

The mass rate of organics leaving the condenser vent was determined from the measurement of the vent flow rate and concentration. Table F-68 presents the source testing results for the Site 26 condenser system.

The condenser system removal efficiency for the major component (1,2-dichloroethane) was consistently above 99 percent. However, as the vapor-phase concentration decreases and the volatility of individual constituents increases, the condenser efficiency drops. Solubility of the vapor constituents in the condensate also may affect condenser efficiency.

The overall mass flow rates from the condenser vent average about 20 Mg/yr of VO for this system. These rates represent emissions from the

TABLE F-68. SOURCE TESTING RESULTS[a] FOR TSDF SITE 26, STEAM STRIPPER OVERHEAD TREATED BY CONDENSER SYSTEM[86]

Constituent	Average vent mass flow rate, g/s	Average condenser system organic removal efficiency,[b] %	Condenser system organic removal efficiency range, %
Vinyl chloride	0.084	6	(0-15)
Chloroethane	0.043	47	(32-65)
1,1-Dichloroethene	0.031	15	(0-53)
1,1-Dichloroethane	0.013	88	(83-94)
1,2-Dichloroethene	0.0098	84	(73-94)
Chloroform	0.11	96	(93-99)
1,2-Dichloroethane	0.34	99.5	(99.2-99.8)
Total VO, g/s (Mg/yr)	0.63 (20)		

TSDF = Treatment, storage, and disposal facility.
VO = Volatile organics.

[a]This table describes the TSDF Site 26 condenser system efficiency as evaluated from the mass flow rates of constituents entering the water-cooled primary condenser and leaving the glycol-cooled secondary condenser vent.

[b]Based on the propane tracer measurement of vapor flow rate.

secondary condenser cooled with glycol at about 2 °C. The emission rates would be expected to be higher for condensers cooled only with cooling tower water at ambient temperatures (e.g., 25 °C).

The overall condenser removal efficiency for total VO is high because the removal is dominated by the high loading of a single constituent (1,2-dichloroethane). An average VO loading of 68 g/s is reduced to an average vent rate of 0.63 g/s and represents a VO control efficiency of 99.1 percent.

F.2.3 Volatile Organic Removal Processes

F.2.3.1 Steam Stripping.

F.2.3.1.1 Site 27. Tests were performed on the Site 27 steam stripper on January 13 and 14, 1988. The Site 27 plant produces linear alkyl benzenes for use in detergent manufacturing by catalytic reaction of C_{10}-C_{14} parafins with benzene. The feed to the stripper generally contains between 1,500 and 2,000 ppm benzene. The treated wastewater contains approximately 1 ppm benzene and is discharged to an aerated lagoon for further treatment. An overhead stream is produced that is 3 to 6 percent benzene.

Wastewater streams are generated from raw benzene purification, catalyst regeneration, off-specification products, storm water, and laboratory and maintenance operations. These streams are combined and collected in a 1,100 m^3, floating-roof, benzene-contaminated wastewater storage tank. This tank serves to equalize any variation in flow rate or concentration. The tank uses a floating roof to contain emissions. A skimming system removes any hydrocarbon layer that may develop on top of the water layer and transfers this to a drag tank.

The stripper feed is pumped from the storage tank through a preheat exchanger and then enters near the top of the steam stripper at a maximum mass flow rate of 3,600 kg/h. Steam is injected at the bottom of the column at a maximum mass flow rate of 442 kg/h and flows countercurrent to the feed. The steam stripping tower contains two, 3.7 m, packed sections and has a diameter of 36 cm. The overall length of the column is 13 m.

The steam stripper remains idle until the liquid level of the holding tank reaches 50 to 60 percent full. This process normally takes 1 to 2

days. The steam stripper is operated somewhere between 10 percent and 20 percent of the time.

The treated or "stripped" effluent exiting the bottom of the column flows through a preheat exchanger (serves to preheat the incoming waste) and ultimately to an aerated wastewater lagoon at an adjoining facility. The overhead vapors emanating from the top of the packed tower are liquified in a water-cooled condenser and collected in a baffled, overhead collection vessel. The aqueous phase is recycled to the top of the stripping column while the organic-rich phase is collected in a dedicated storage tank. The overhead collection vessel is under a nitrogen purge and vents to the flare system.

The primary objective of the test was to obtain data on the effectiveness of steam stripping on removing volatile and semivolatile organics from aqueous wastes. Additional objectives included assessment of the effectiveness of the overhead condenser and characterization of the treated and untreated waste. Liquid samples of feed, bottoms, aqueous condensate, and recovered organic condensate were collected. Bottoms samples (treated wastewater) were taken five times over a 16-h period. The other liquid streams were sampled two to three times in the same period. Condenser vent (gaseous) samples were taken three times in the course of the test. Process data, including feed and steam flow rates, feed overhead vapor and overhead condensate temperatures, and steam and column pressure were collected throughout the test period. The efficiency of the condenser could not be evaluated, as flow rates were unavailable for the organic condensate and the condenser vent gas. Condensed vent gas was routed to a flare system to control atmospheric emissions.

Liquid samples were analyzed for volatile and semivolatile organics using EPA Methods 8240[87] and 8270.[88] Vent gas samples were collected on charcoal tubes, extracted and analyzed by NIOSH Method 127.[89] Source testing results based on averages of two sets of complete samples are given in Table F-69. Note that total VO data in this table is the sum of the four listed chemical constituents.

F.2.3.1.2 Site 25.[90] Tests were performed on the Site 25 steam stripper on September 24 and 25, 1986. The Site 25 plant produces one-carbon chlorinated solvents such as methylene chloride, chloroform, and

TABLE F-69. SOURCE TESTING RESULTS FOR SITE 27, STEAM STRIPPER

Constituent	Influent to stripper		Effluent from stripper		Overhead condensate				Steam-stripper organic removal efficiency[a,b] wt %	Condenser vent emissions,[c] Mg/yr
					Aqueous		Organic			
	Mass flow rate, kg/h	Conc., ppmw	Mass flow rate, x 10^3 kg/h	Conc., ppmw	Mass flow rate, kg/h	Conc., ppmw	Mass flow rate, kg/h	Conc., ppmw		
Acetone	<0.034	<10	<36	<10	NM	2750	NM	850	NA	NA
Benzene	2.23	665	<18	<5	NM	897	NM	2,250	>99	NA
Trans-1,2-dichloroethene	<0.034	<10	<36	<10	NM	<10	NM	<10	NA	NA
Toluene	0.12	37	<18	<5	NM	<5	NM	<5	>85	NA
Purgeable organic carbon	0.040	11.9	21	5.9	NM	43.4	NM	NS	>47	NA
Total VO[d]	2.36	702	<36	<10	NM	3,650	NM	3,100	>98	NA

NA = Not available.
NM = Not measured.
NS = Not sampled.
[a]Based on assumed bottoms flow rate of 3,630 kg/h.
[b]Based on difference in mass flow between stripper influent and effluent.
[c]Acetone and benzene were measured at 64 ppmv and 4,200 ppmv in the vent gas, but no vent gas flow rate was available.
[d]Total VO refers to the sume of the four identified constituents in the table.

carbon tetrachloride. The steam stripper is used to recover solvents and to treat the plant's wastewater. The major contaminants that are recovered and monitored by the plant include methylene chloride, carbon tetrachloride, and chloroform with National Pollutant Discharge Elimination System (NPDES) discharge limits of 50, 55, and 75 ppb, respectively. Plant analyses showed variable concentrations in the feed stream to the steam stripper, ranging from hundreds of parts per million to saturation of the water phase with organics and concentrations in the effluent generally on the order of 50 to 75 percent of the NPDES discharge limits.

The wastewater at this plant consists of reactor rinse water and rainfall collected from diked areas around the plant; consequently, the flow rate and composition of the wastewater is cyclical and dependent on the amount of rain. Plant personnel indicated that the steam stripper operated roughly 75 percent of the time with accumulation in storage when the stripper is not operating. Once the stripper is started, it operates in an essentially continuous mode until the wastewater in storage has been steam-stripped.

Site 25 wastewater enters one of two decanters (each approximately 76 m^3) where it is processed as a batch. Sodium hydroxide solution (caustic) is added to the decanter to adjust the pH, and flocculants are added to aid in solids removal. The mixture is recirculated and mixed in the decanter and allowed to settle. The wastewater (upper layer) is sent to the stripper feed (or storage) tank (approximately 470 m^3). The organic layer (on the bottom) is removed periodically from the decanter and sent to a surge or collection tank, and solids are removed periodically with a vacuum truck for disposal. The cycle time for a batch of wastewater in the decanter is about 1 day.

The steam stripper feed passes through a heat exchanger for preheating by the effluent from the stripper. The stripper column is packed with 2.5-cm saddles and processes about 0.8 L/s. The stripper effluent, after cooling by the heat exchanger, enters one of two open-topped holding tanks (about 19 m^3) where the pH is adjusted and analyzed for comparison with the discharge limits. If the analysis is satisfactory, the water is pumped to a surge tank for final discharge to the river under the NPDES permit. The

overhead vapors from the stripper pass through the condenser system described in Section F.2.2.3.1.

The primary objective of the field test of the steam-stripping process at Site 25 was to determine how efficiently it removes VO from the wastewater. Liquid samples were taken from the stripper feed, bottoms, and condensate five times at approximately 2-h intervals during the day shift for each of the 2 days of testing. The samples were taken in 40-mL glass VOA vials with septa and no headspace. Vapor samples were taken three times each test day from the primary condenser vent, secondary or tank condenser vent, and the vent of the stripper's feed (storage) tank. Vapor samples also were collected over the open organic collection tank and from the decanter vent prior to the vent condenser. The vapor samples were taken in evacuated electropolished stainless steel canisters. Process data were collected throughout the test. Process data included the feed flow rate and temperature, steam flow rate and temperature, cooling water temperature, column pressure drop, heat exchanger temperature, and outage measurements for the holding tanks.

Samples for VO initially were analyzed by GC-MS using EPA Method 624. After the individual components were identified by GC-MS, the compounds were quantified by EPA Method 601.[91] Method 601 is a purge-and-trap procedure that is used for analysis of purgeable halocarbons by GC. The Method 601 results are reported for aqueous samples. The level of VO in the organic phase was determined by direct-injection GC. All of the vapor samples were analyzed by GC with calibration standards for the components of interest. Source testing results for the Site 25 steam stripper are given in Table F-70.

F.2.3.1.3 Site 26.[92] Tests were performed on the Site 26 steam stripper on July 22 and 23, 1986. The Site 26 plant produces 1,2-dichloroethane (ethylene dichloride [EDC]) and vinyl chloride monomer. Wastewaters from the production processes and from other parts of the plant, including stormwater runoff, are collected in a feed tank from which the waste is pumped into the steam-stripper column. The organics are stripped from the waste and condensed overhead in a series of two condensers described in Section F.2.2.3.2. Approximately 2,400 Mg/yr of VO are removed from the

TABLE F-70. SOURCE TESTING RESULTS FOR TSDF SITE 25, STEAM STRIPPER

Constituent	Influent to stripper		Effluent from stripper		Overhead		Steam-stripper organic removal efficiency,[a] wt %	Vent emissions,[b] Mg/yr
	Mass flow rate, g/h	Conc., ppmw	Mass flow rate, g/h	Conc., ppmw	Flow, kg/h	Conc., ppmw		
Chloromethane	79.6	32.6	<0.014	<0.005	NA	NA	>99.98	0.51
Methylene chloride	10,800	4,490	<0.028	<0.011	9.25	787,000	>99.999	39
Chloroform	3,090	1,270	<0.017	<0.006	2.50	213,000	>99.999	12.1
Carbon tetrachloride	134	54.8	<0.014	<0.005	NA	NA	>99.98	4.9
Trichloroethylene	13.7	5.6	<0.014	<0.005	NA	NA	>99.8	NA
1,1,2-Trichloroethane	13.0	5.3	<0.014	<0.005	NA	NA	>99.8	NA

TSDF = Treatment, storage, and disposal facility.
NA = Not available.

[a]Based on fraction of influent mass not accounted for in stripper bottoms.

[b]Total emissions from steam stripper, solids decanter, and storage tank, based on operation of 50 wk/yr.

waste stream. The entire condensate, both aqueous and organic phases, is recycled to the production process. The effluent stream from the stripper column is sent through a heat exchanger to help preheat the feed stream and then is sent to a WWT facility.

No design information is available for the tray steam-stripper column. Typically, the feed rate is about 850 L/min to the column operating at 136 kPa. Steam is fed at 446 kPa and at 146 °C at a rate of about 1,700 kg/h.

The objective of the field test of the steam-stripping process at Site 26 was to determine how efficiently it removes VO from hazardous waste streams. Liquid samples were taken from the stripper influent and effluent and from the overhead condensate aqueous and organic streams. Air emissions from the condenser vent also were sampled. Sampling was conducted over 2 days with samples taken five times at 2-h intervals on each day. Liquid grab samples were collected in 40-mL VOA vials. Gas vent samples were collected in evacuated stainless steel canisters. Process data were collected at half-hour intervals throughout the testing. Process operation data collected included feed, effluent, condensate, and steam flow rates; temperatures of the feed, effluent, and condensate; and the steam pressure.

The VO in the water samples were analyzed by a purge-and-trap procedure with separation and quantification performed by GC-MS analysis (EPA Method 624). The organic phase in the condensate was analyzed by direct-injection GC. The vent gas analysis procedures are detailed in the site-specific test and quality assurance plan dated July 7, 1986, but were not presented in the report.

Stream flow and concentration data were used to characterize all process streams around the steam stripper. Table F-71 presents the source testing results including average stream mass flow and composition data for each stream entering and leaving the Site 26 steam stripper as well as organic removal efficiencies. The organic removal efficiency for the steam stripper was calculated on the basis of influent and effluent flows from the stripper. The composition data available for the condensate are presented in Table F-71 but are not used to calculate removal efficiencies. This is done because of the need to see the actual amount of organic

TABLE F-71. SOURCE TESTING RESULTS FOR TSDF SITE 26, STEAM STRIPPER

Constituent	Influent to stripper		Effluent from stripper		Overhead condensate[a]				Steam-stripper organic removal efficiency	Condenser vent emissions
					Aqueous		Organic			
	Mass flow rate, kg/h	Conc., ppmw	Mass flow rate, x 10^6 kg/h	Conc., ppmw	Mass flow rate, kg/h	Conc., x 10^{-3} ppmw	Mass flow rate, kg/h	Conc., x 10^{-3} ppmw	wt %	Mg/yr
1,2-Dichloroethane	270	5,600	4,900	0.097	110	95[b]	190	870[b]	99.998	11
Chloroform	13	270	480,000	9.6	11	9.1[b]	15	70[b]	96	3.5
Benzene	0.0098	0.20	<500	<0.01[c]	NA	NA	NA	NA	>95	NA
Carbon tetrachloride	0.083	1.7	<500	<0.01[c]	NA	NA	NA	NA	>99.4	NA
Chlorobenzene	0.017	0.34	<500	<0.01[c]	NA	NA	NA	NA	>97.0	NA
Chloroethane	0.47	9.6	<500	<0.01[c]	NA	NA	NA	NA	>99.9	1.4
1,1-Dichloroethane	0.54	11	<500	<0.01[c]	NA	NA	NA	NA	>99.9	0.41
1,1-Dichloroethene	0.23	4.7	<500	<0.01[c]	NA	NA	NA	NA	>99.8	0.98
1,2-Dichloroethene	0.44	8.9	<500	<0.01[c]	NA	NA	NA	NA	>99.9	0.31
Methylene chloride	0.059	1.2	<500	<0.01[c]	NA	NA	NA	NA	>99.2	NA
Tetrachloroethene	0.069	1.4	<500	<0.01[c]	NA	NA	NA	NA	>99.3	NA
1,1,2-Trichloroethane	0.37	7.5	<500	<0.01[c]	NA	NA	NA	NA	>99.9	NA
Trichloroethene	0.24	4.8	<500	<0.01[c]	NA	NA	NA	NA	>99.8	NA
Vinyl chloride	0.41	8.4	<500	<0.01[c]	NA	NA	NA	NA	>99.9	2.6
Total VO	290[d]	5,900	500,000	9.8	121	100	220	940	>99.8	20

TSDF = Treatment, storage, and disposal facility.
NA = Not analyzed for this constituent.
VO = Volatile organics.

[a]Not used for calculation of removal efficiencies because of need to determine actual organic removed and incompleteness of condensate analyses.

[b]Only chloroform and 1,2-dichloroethane were analyzed in the condensate. Because of the use of average flows and average concentrations, the component mass balance for these components may not be as close as was usually obtained at a given sampling time.

[c]All concentrations were below detection limit.

[d]Calculated as sum of quantified organic compounds.

removed from the wastewater and because of the incompleteness of the condensate data.

F.2.3.1.4 Site 5.[93] Field evaluations were performed on November 20, 1985, of the steam-stripping system at Site 5. Section F.2.2.2 contains a description of Site 5 and an evaluation of the liquid-phase carbon adsorption system at the facility. The following paragraphs describe the steam-stripping system at Site 5.

Wastewater from a feed tank is pumped to the steam-stripping column where the organics are steam-stripped in the column and condensed from the overhead stream. The stripped organics are separated from the condensed steam in the organic condensate tank. The aqueous layer is recycled from the organic condensate tank to the feed tank. The organic phase is sent to a vented storage tank. From there, the organics are transferred to tank trucks and taken offsite for resale as fuel.

The steam-stripping column is 19.2 m high with an internal diameter of 0.46 m. The column is packed with 3.17 m^3 of 2.5-cm diameter stainless steel rings. The steam stripper operates with a gas-to-liquid ratio ranging from 55 m^3/m^3 at the bottom of the column to 24 m^3/m^3 at the top of the column. Steam is fed to the column at approximately 130 °C and 365 kPa pressure at a feed-to-steam ratio of 14.7 kg/kg.

The objective of the field test of the steam-stripping process at Site 5 was to determine how efficiently it removes VO from hazardous waste streams. Liquid and gas samples were collected and process parameters measured at various points in the steam-stripping system. Liquid samples were collected from the steam-stripper influent and effluent and from the overhead aqueous and organic condensates. Emissions from the condensate tank vent were sampled. Sampling was conducted over a 2.5-h period with an average of four samples collected from each sampling point. Liquid grab samples were collected in 40-mL VOA bottles. Gas vent samples were collected in evacuated stainless steel canisters. Process operating data were collected over a 4.5-h period to ensure that the process was operating at steady state. Process data collected included feed, steam, and vent gas flow rates, temperatures, and pressures.

Vent gas was analyzed using GC-FID; identifications were confirmed with GC-MS. The VO in the liquid samples were speciated and quantified using a Varian Model 3700 GC. Material and energy balances and stream flow and concentration data were used to characterize all process streams around the steam stripper. Table F-72 presents the Site 5 steam stripper source testing results.

The steam-stripper organic removal efficiency was calculated based on the influent and effluent flows for the stripper. The composition data for the overhead streams are presented but are not used to calculate removal efficiencies. This is done to show the actual removal of organics from the waste stream. It also minimizes any background interference effects for the wastewater. By looking at the same bulk stream of liquid, the same liquid background is present, allowing for consistency between samples.

F.2.3.1.5 Site 28.[94] Source testing was conducted from December 3 through 5, 1984, on the Site 28 steam stripper. Site 28 is engaged in the reclamation of organic solvents for recycle and sale. The live steam-stripping process is used for organic solvent reclamation. This system is located inside a building that also contains three 3.8-m^3 waste solvent storage tanks and three 3.8-m^3 product storage tanks. The building also is used for drum storage. There are five 38-m^3 outside storage tanks that are used primarily for contaminated solvent and residue storage. An oil/gas-fired boiler system is used for process steam generation. An analytical laboratory is maintained in the building that houses company offices.

The contaminated organics processed by Site 28 are generated mostly by the chemical, paint, pharmaceutical, plastics, and heavy manufacturing industries. The types of chemicals recovered include the following VO: ketones, aromatic hydrocarbons, chlorinated solvents, freons, and petroleum naphthas. The recovered products may be recycled back to the generator or marketed to suitable end users. Generally, 50 to 70 percent solvent recovery from the waste stream is expected. Residues from the stripping process are solidified by mixing with sorbents and shipped offsite to be landfilled.

Contaminated organic solvents are charged to the stripper tank in a batch operation. Steam is injected through spargers into the tank. The

TABLE F-72. SOURCE TESTING RESULTS FOR TSDF SITE 6, STEAM STRIPPER

Constituent	Influent to stripper		Effluent from stripper		Overhead condensate				Steam-stripper organic removal, wt %	Process[a] air emissions, x 10^3 Mg/yr
					Aqueous		Organic			
	Mass flow rate, kg/h	Conc., ppmw	Mass flow rate, kg/h	Conc., ppmw	Mass flow rate, kg/h	Conc., ppmw	Mass flow rate, kg/h	Conc., x 10^{-3} ppmw		
Nitrobenzene	15.0	500	1.29	40	0.812	1,900	12.12	787	91.4	<1.1
2-Nitrotoluene	2.33	78	0.076	2.4	0.037	87	2.97	193	96.7	<1.1
4-Nitrotoluene	1.53	51	0.139	4.4	0.019	45	1.49	97	90.9	<1.1
Total VO[b]	18.9	630	1.51	47	0.868	2,000	16.6	1,080	92.0	<3.3

TSDF = Treatment, storage, and disposal.
VO = Volatile organics.

[a]Condenser vent emissions.

[b]Total of three quantified organics.

stripper volume is circulated and pumped into the steam line for enhanced contact between the steam and the stripper liquid. The stripped organics and steam leaving the tank are directly condensed overhead and enter a decanter. The decanter then contains two immiscible phases and, upon completion of the batch stripping, the organic phase is decanted to a storage tank and the aqueous phase enters a miscible solvent tank. The aqueous residual currently is being landfilled. The recovered solvents are recycled or sold.

The horizontal stripping tank has a volume of 1.9 m^3 with a steam sparger running lengthwise along the bottom of the tank. Steam is usually supplied at 240 kPa and at unknown temperature at a rate of about 250 kg/h.

The objective of the field test of the steam-stripping process at Site 28 was to determine how efficiently it removes volatiles from hazardous waste streams. Liquid and gas samples were collected and process parameters measured at various points in the steam-stripping process. Liquid samples were collected from the steam-stripper influent, condensate, miscible solvent tank, and recovered VO storage tank. Gas samples were collected from the condenser, miscible solvent tank, and recovered VO storage tank vents. In addition, the volumes of liquid in the steam stripper, miscible solvent tank, and recovered VO storage tank were monitored.

Four batch tests were performed with the steam-stripper system. The four batch charges contained: (1) aqueous xylene, (2) 1,1,1-trichloroethane/oil, (3) aqueous 1,1,1-trichloroethane, and (4) aqueous mixed solvents. Each batch was sampled and monitored in the same fashion. The liquid stripper contents were sampled at the beginning and end of each batch test, with two intermediate samples taken. Liquid distillate samples were taken at the end of the process, and gas vents were tested near the midpoint of the process. Liquid grab samples were collected in 40-mL VOA bottles. Gas vent samples were collected in evacuated stainless steel canisters. Process data were collected periodically for the distillate rate, overhead vapor temperature, and steam pressure and rate, and all other process data were gathered at the start or finish of the operation.

Vent gas was analyzed by headspace GC-analysis method. The VO in the liquid samples were speciated and quantified by direct-injection GC and

headspace GC. Material and energy balances and process volume and concentration data were used to characterize the batch stripping process. Site 28 steam stripper source testing results are presented in Table F-73. The organic removal efficiency was calculated on the basis of initial and final mass of a constituent in the stripper tank. The composition data for the overhead streams are presented but are not used to calculate removal efficiencies. This is done because of difficulties in measuring the batch volumes in combination with high organic removal efficiencies obtained. Removing small, final amounts of a constituent from the stripper tank would change the organic removal efficiency but would not significantly change the volume in the condensate receiving tanks. By looking at the same bulk volume of material, the actual amount of organic removed from the waste is determined. This also removes the effect of any receiver tank contamination, volume reading bias for the stripper tank, or background interference in the liquid.

F.2.3.1.6 Site 29.[95] Tests were performed August 18 and 19, 1984, on the Site 29 steam stripper. The steam stripper at Site 29 is used to remove VO, especially methylene chloride, from aqueous streams. The steam stripper removes 38.6 Mg/yr VO from the waste streams.

A process waste stream consisting of methylene chloride, water, salt, and organic residue is fed to the steam stripper in which much of the VO is stripped and taken overhead. The overhead vapor is condensed, with the aqueous phase being recycled to the column and the organic phase stored for reuse. The bottoms stream is used to preheat the incoming waste. Then it is either sent to a publicly owned treatment works or sent back into a tank for the feed stream, depending on whether the effluent meets discharge limits. If the midpoint temperature of the stripping column is above a given setpoint, the effluent meets limitations and is sent to the treatment facility.

The stripping column contains 3.0 m of 1.6-cm pall rings and has a diameter of 0.20 m. The waste stream feed rate is approximately 19 L/min with an overhead organic product rate of about 0.28 L/min. Steam was fed at a pressure range of 190 to 320 kPa, although the temperature and rate were unspecified.

TABLE F-73. SOURCE TESTING RESULTS[a] FOR TSDF SITE 28, STEAM STRIPPER

Constituent	Initial stripper charge		Final stripper residue		Overhead condensate[c]				Steam stripper organic removal efficiency, wt %	Process[d] air emissions, x 10^3 Mg/yr
					Aqueous		Organic			
	Mass, kg	Conc.,[b] ppmw	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw		
Batch 1										
Acetone	0.049	39	<0.0086	<6	0.087	350	<0.3	<1,000	91	NA
Isopropanol	1.2	960	<0.0086	<6	2.79	11,000	<0.3	<1,000	99.6	4.5
Methyl ethyl ketone	1.3	1,040	0.048	34	1.68	6,600	<0.3	<1,000	96	19
1,1,1-Trichloroethane	0.21	170	0.028	20	0.2	1,100	<0.3	<1,000	87	4.2
Tetrachloroethene	0.36	290	<0.028	<20	0.04	160	4.3	11,000	96	2.3
Ethyl benzene	16[f]	360	0.14	100	<0.001	<4	19	57,000	99.1	3.9
Toluene	16[f]	86	0.06	42	<0.001	<3	16	49,000	99.6	16
Xylene	76[f]	2,000	0.38	270	0.006	25	87	260,000	99.5	8.5
Total VO[e]	110	4,900	0.68	480	4.8	19,000	120	380,000	99.4	58
Batch 2										
1,1,1-Trichloroethane	590	660,000	1.3	4,100	220	560,000	520	770,000	99.8	1.9
Methyl ethyl ketone	67	75,000	<0.0024	<7	1.6	4,000	25	37,000	100	77
Total VO[e]	660	740,000	1.3	4,100	220	560,000	550	810,000	99.8	79
Batch 3										
1,1,1-Trichloroethane	100	180,000	6.5	12,000	100	560,000	33	730,000	94	NA
Methyl ethyl ketone	0.18	320	<0.0038	<7	0.22	1,200	0.6	14,000	99	NA
Acetone	0.16	290	<0.0032	<6	0.20	1,100	<0.004	<1,000	99	NA
Ethyl benzene	0.025	44	0.0065	12	0.006	35	1.7	38,000	74	NA
Isopropanol	0.021	37	<0.0032	<6	0.027	160	<0.004	<1,000	<85	NA
Total VO[e]	100	180,000	6.5	12,000	100	560,000	35	780,000	94	NA

See notes at end of table.

(continued)

TABLE F-73 (continued)

Constituent	Initial stripper charge		Final stripper residue		Overhead condensate[c]				Steam stripper organic removal efficiency wt %	Process[d] air emissions, x 10^3 Mg/yr
					Aqueous		Organic			
	Mass, kg	Conc.,[b] ppmw	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw		
Batch 4										
Acetone	2.3	6,500	<0.002	<6	3.2	23,000	<0.004	<1,000	99.96	NA
Isopropanol	0.03	95	NA	NA	0.035	250	<0.004	<1,000	NA	NA
1,1,1-Trichloroethane	0.78	2,200	0.080	230	1.4	10,000	0.13	40,000	90	NA
Tetrachloroethene	0.02	55	NA	NA	0.029	210	<0.024	6,000	NA	NA
Toluene	0.03	869	0.012	35	0.0032	23	<0.004	<1,000	NA	NA
Xylene	0.001	49	0.042	120	0.045	320	0.86	270,000	NA	NA
Total VO[e]	3.489	9,700[h]	0.14	390	4.6	34,000	0.99	310,000	96	NA

TSDF = Treatment, storage, and disposal facility.
NA = Not available.
VO = Volatile organics.

[a]This table describes the mass balance around the steam stripper at Site 28 for four different waste mixtures and the treatability of different compounds in different matrices. For two waste mixtures, air emissions from the condenser vent have been estimated.

[b]Concentrations given for liquid charged to batch stripper.

[c]Not used to calculate overhead removal because of volume reading difficulties, possible receiver tank contamination, and the need to calculate actual amount of organic removed from waste stream.

[d]Condenser vent emissions based on 24 h/d, 5 d/wk operation.

[e]Total of compounds accounted for.

[f]Accidental inclusion of an unknown xylene/aromatic mixture. Estimated initial masses from final results.

[g]Below amount expected due to unmixed sample collected.

[h]Estimated from later concentration.

The objective of the field test of the steam-stripping process at Site 29 was to determine how efficiently it removes volatiles from hazardous waste streams. Liquid samples were collected from the process waste feed, stripper effluent, and organic overhead condensate. Air emissions from the product receiver tank vent also were sampled. Sampling of the influent and effluent was conducted approximately hourly for 5 h on the first day and 12 h on the second, although a shutdown and restart delay of 6 h occurred on the second day because of instrument difficulties. Liquid grab samples were collected in either a glass or stainless steel beaker and then distributed into individual glass bottles for analysis. A composite sample of the organic product was collected in glass bottles after completion of the test. Gas vent samples were collected in evacuated glass sampling bulbs. Process data collected included feed flow rate; column, feed, effluent, and vent temperatures; and steam pressure.

Vent gas was analyzed using GC-FID (Method 18).[96] The VO in the liquid samples were analyzed by GC-MS (Method 8240).[97] Material and energy balances and stream flow and concentration data were used to characterize all process streams around the steam stripper. Table F-74 presents the source testing results.

F.2.3.2 Air Stripping.

F.2.3.2.1 Site 24.[98] A test program was conducted for 4 days during May 1985 on the Site 24 air stripping system. Site 24 is an NPL Superfund site currently managed by EPA under CERCLA. It is a 1.6-ha abandoned waste disposal facility that operated from 1962 to 1970. Several lagoons were used to dispose of various liquids and sludges during operation of this dump.

In response to citizen complaints received in early 1983, EPA installed monitoring wells, a security fence, and a soil cap and regraded portions of the site during these initial actions. A leachate collection and treatment system also was installed by EPA at this time. The treatment system consisted of an induced-draft air stripper. Air is drawn countercurrently to the water flow, and, upon leaving the column, the air passes through granular-activated carbon before entering the atmosphere. The effectiveness of the gas-phase carbon adsorption system is discussed in

TABLE F-74. SOURCE TESTING RESULTS FOR TSDF SITE 29, STEAM STRIPPER

Constituent	Influent to stripper		Effluent from stripper		Overhead condensate[a]		Steam stripper organic removal efficiency, wt %	Process air emissions,[b] x 10^3 Mg/yr
	Mass flow rate, kg/h	Conc., mg/kg	Mass flow rate, x 10^6 kg/h	Conc., mg/kg	Mass flow rate, x 10^3, kg/h	Conc., mg/kg		
Methylene chloride	4.6	3,900[c]	789	0.086	88	5,200	>99.99	1,400
Chloroform	0.067	57	6,000	5.1	19	1,100	91	13
Carbon tetrachloride	--[d]	--[d]	<290[e]	<0.250[f]	<0.043	<2.5	NA	4.7
Total VO	4.7	3,900	6,000	5.2	107	6,300	99.8	1,400

TSDF = Treatment, storage, and disposal facility.
NA = Not available.
VO = Volatile organics.

[a]Not used for calculation of removal efficiencies because of desire to see actual removal from waste stream and to remove any background interference effects.

[b]Product receiver tank vent flow rate equals 1 L/s.

[c]Calculated from average concentrations and average influent flow rate.

[d]Twelve of thirteen analyses below reliable detection limit.

[e]Some concentrations observed were below the detection limit; results presented are averages over 13 samples with samples below detection limit averaged as zero.

[f]All analyses below reliable detection limit.