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EIS



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

Volume II-Appendices

PRELIMINARY DRAFT



NOTICE This document has not been formally released by EPA and should not now be construed to represent Agency policy. It is being circulated for comment on its technical accuracy and policy implications.

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

Volume II-Appendices

PRELIMINARY DRAFT

Emission Standards Division

U. S. ENVIRONMENTAL PROTECTION AGENCY Office of Air and Radiation Office of Air Quality Planning and Standards Research Triangle Park, North Carolina 27711

March 1988

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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	<pre>meters X 3.28 = feet centimeters X 0.396 = inches</pre>
kPa - kilopascals	<pre>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</pre>
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
	k₩/28.3 m ³	1.341 hp/10 ³ ft ³
	kPa•m ³ /g•mol	0.0099 atm•m ³ /g•mol

APPENDIX A

EVOLUTION OF PROPOSED STANDARDS

APPENDIX A

EVOLUTION OF PROPOSED STANDARDS

The EPA Office of Solid Waste and Emergency Response (OSWER) first initiated the development of air emission standards for hazardous waste treatment, storage, and disposal facilities (TSDF) in 1978. In December 1978, OSWER proposed air emission standards for treatment and disposal of hazardous waste based on an approach that included definition of volatile waste solely in terms of its vapor pressure and use of the U.S. Occupational Safety and Health Administration (OSHA) levels for determining acceptable emission levels (43 FR 59008, December 18, 1978). A supplemental notice of proposed rulemaking was published on October 8, 1980 (45 FR 66816).

The 1978 and 1980 actions were reproposed in 1981 (46 FR 11126, February 5, 1981); the proposed standards included requirements for systems to monitor ambient air quality and gaseous emissions, sampling and analysis plans, data evaluation by predictive models, and recordkeeping/reporting. General control requirements to prevent wind dispersion of particulate matter from land disposal sources also were proposed. The final standards adopted by EPA included the particulate control requirements, but they did not incorporate any other measures for air emission management (47 FR 32274, July 26, 1982).

In February 1984, EPA considered the need to further evaluate air emission standards and delegated authority to the Office of Air Quality Planning and Standards (OAQPS) to develop standards for air emissions from area sources at TSDF. At that time, OAQPS initiated the project that led to this draft background information document (BID). The program plan outlining the technical and regulatory approaches selected for the project was reviewed by the National Air Pollution Control Technique Advisory Committee (NAPCTAC) meeting held August 29-30, 1984. In November 1984, Congress passed the Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) of 1976. Section 3004(n) of HSWA specifically directs the Administrator to establish standards for the monitoring and control of air emissions from hazardous waste TSDF as necessary to protect human health and the environment. It is under the authority of Section 3004(n) that these standards are being developed.

This OAQPS study to develop air standards for TSDF air emissions began with the collection of information on waste management processes, hazardous waste characteristics, and controls that could potentially be applied to reduce air emissions. This information was obtained through site visits and sampling surveys, OSWER permit data and industry surveys, various Agency data bases, and testing programs. Additional information was gathered through literature searches, meetings, and telephone contacts with experts within EPA, State and local regulatory authorities, and affected industries. Based on this information, preliminary draft BID chapters, which described the TSDF industry, emission sources, and potential controls were prepared and transmitted to representatives of industry, trade associations, and environmental groups for review and comment in February 1985. The comments received were analyzed and incorporated in the BID, as was additional data obtained through test programs, updated permit information, field trips, other data bases, and internal review through EPA Working Group meetings.

Public comments were also solicited on three specific aspects of the project. In February 1987, comments were solicited from TSDF operators, major trade associations, and environmental groups on potential volatile organics (VO) test methods. In April 1987, a draft report on predictive models for estimating organic air emissions was mailed out for public review. (This report was finalized and distributed December 10, 1987.) On June 9, 1987, OAQPS presented a status report on the project and test method development work at a public meeting of the NAPCTAC.

Under a separate project, the OAQPS prepared, on an accelerated schedule, its initial set of TSDF air standards. In early February 1987, EPA published the proposed standards in the <u>Federal Register</u> (52 FR 3748, February 5, 1987). At that time, EPA requested comments from TSDF operators, trade associations, and environmental groups on the proposed air controls for organic air emissions from equipment leaks and process vents

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on distillation and separation units at TSDF with waste streams containing 10 percent or more total organics. The proposed standards were developed on an accelerated schedule based on technology transfer from Clean Air Act standards applicable to the synthetic organic chemical manufacturing industry and petroleum refineries. A public hearing was held on March 23, 1987, in Durham, North Carolina, to obtain external comments on the proposed standards.

This BID reflects revisions that have been made since transmittal of the preliminary draft in February 1985. It does not reflect decisions on the accelerated air standards. Comments received will be considered in a revised draft following the upcoming review by the NAPCTAC and the public. The NAPCTAC is composed of 16 persons from industry, State and local air pollution agencies, environmental groups, and others with expertise in air pollution control. This meeting, tentatively scheduled for May 17, 1988, will be open to the public and will provide an opportunity for industry and environmental groups to comment on the draft rulemaking prior to proposal in early 1989. Major events that have occurred to date in the development of background information for this preliminary draft BID are presented in Table A-1.

^{*}NOTE: This discussion will be updated prior to proposal to reflect events as they occur between now and proposal.

Date	Event
November 1983	Contractors begin site visits and source sampling at over 100 TSDF; testing under OAQPS/ORD/OSW program extending through 1986 also begins.
December 1983	Meeting with Chemical Manufacturers Association to review "Evaluation and Selection of Models for Estimating Air Emissions from Hazardous Waste Treatment, Storage, and Disposal Facilities," "Assessment of Air Emissions from Hazadous Waste Treatment, Storage, and Disposal Facilities: Hazardous Waste Rankings," and "Assessment of Air Emissions from Hazardous Waste Treatment, Storage, and Disposal Facilities: Preliminary National Emissions Estimates."
February 1984	OSWER delegates authority for development of air standards for TSDF area sources to OAQPS.
August 29-30, 1984	National Air Pollution Control Techniques Advisory Committee meeting held in Durham, North Carolina, to review TSDF program plan (49 FR 26808).
November 9, 1984	Congress passes Hazardous and Solid Waste Amendments to Resource Conservation and Recovery Act of 1976.
November 9, 1984	Meeting with Chemical Manufacturers Association Secondary Emissions Work Group to review and comment on draft technical note, "Basis for Design of Test Facility for Flux Chamber Emissions Measurement Validation."
April 24, 1985	Meeting with American Petroleum Institute to discuss status of standards development for land treatment.
January 8, 1985	Meeting with Chemicals Manufacturers Association to discuss current studies of air source emissions from TSDF.
October 1985	Research Triangle Institute begins work to develop air emissions for hazardous waste treatment, storage, and disposal facilities, under EPA Contract No. 68-02- 4326.
ebruary 6, 1986	Mailout of preliminary BID Chapters 3.0 to 6.0 to industry and environmental groups.
larch 6-7, 1986	Meeting with Chevron Chemical Co. to discuss planned landfarm simulation study.

TABLE A-1. EVOLUTION OF PROPOSED TREATMENT, STORAGE, AND DISPOSAL FACILITY AIR STANDARD^a

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Date	Event
April 24, 1986	Meeting with American Petroleum Institute on status of TSDF standards development.
May 14, 1986	Meeting with Chemical Manufacturers Association to discuss project status and BID comments.
December 17, 1986	Meeting with American Petroleum Institute on land treatment air emission research.
February 5, 1987	Proposal of accelerated standards for selected sources at hazardous waste TSDF (52 FR 3748).
February 11, 1987	Mailout of draft test method approach document to industry and environmental groups.
March 23, 1987	Public hearing for accelerated rulemaking for selected sources at hazardous waste TSDF held in Durham, North Carolina.
April 10, 1987	Mailout of draft report on organic air emission models to industry and environmental groups.
June 9, 1987	Meeting of National Air Pollution Control Techniques Advisory Committee to review project status and test method development program (52 FR 15762).
September 30, 1987	Meeting with Chevron Chemical Corporation to discuss land treatment data.
December 10, 1987	Mailout of final report on organic air emission models to industry and environmental groups.
January 14, 1988	Meeting with Chemical Manufacturers Association to discuss project status.
To be determined	Mailout of preliminary draft BID to National Air Pollution Control Techniques Advisory Committee, TSDF operators, trade associations, environmental groups, and other public groups.
To be determined	Meeting of National Air Pollution Control Techniques Advisory Committee to review preliminary draft BID.

- OAQPS = Office of Air Quality Planning and Standards. ORD = Office of Research and Development.
- = Office of Solid Waste. OSW
- = Background Information Document. BID

^aThis table presents those major events that have occurred to date in the development of background information for the TSDF air standard.

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

APPENDIX B

INDEX TO ENVIRONMENTAL CONSIDERATIONS

This appendix consists of a reference system that is cross-indexed with the October 21, 1974, <u>Federal Register</u> (39 FR 37419) containing EPA guidelines for the preparation of Environmental Impact Statements. This index can be used to identify sections of the document that contain data and information germane to any portion of the <u>Federal Register</u> guidelines.

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Ageno regu impac	cy guidelines for preparing latory action environmental ct statements (39 FR 37419)	Location within the Background Information Document (BID)
1. Ba	ackground and description	
a.	. Summary of control strategies	A description of example control strategies is provided in Chapter 5.0.
b.	Industry affected by the control strategies	A discussion of the industry affected by the control strategies is presented in Chapter 3.0.
c.	Relationship to other regulatory Agency actions	The relationship to other regulatory Agency actions is discussed in Chapter 5.0.
d.	Specific processes affected by the control strategies	The specific processes affected by the control strategies are summarized in Chapter 3.0.
2. Impacts of the alternatives		
a.	Air pollution	The air pollution impacts are dis- cussed in Chapters 4.0 and 6.0. Supplementary information on the emission models and emission estimates is included in Appendix C; Appendix D describes the Source Assessment Model used to estimate nationwide emissions and their correlations to test methods. Test data are presented in Appendix F.
b.	Water pollution	The water pollution impacts are described in Chapters 4.0 and 6.0.
с.	Solid waste disposal	The solid waste disposal impacts are discussed in Chapters 4.0 and 6.0.
d.	Energy impact	The energy impacts are discussed in Chapter 6.0.

(continued)

Agency guidelines for preparing regulatory action environmental impact statements (39 FR 37419)	Location within the Background Information Document (BID)
e. Economic impact	The cost impacts of example control strategies are presented in Chapter 7.0; supplementary information on the costing of add-on controls and on the costing of volatile organic removal processes and hazardous waste inciner- ation are included in Appendixes H and I.
f. Health impact	Incidence and risk impacts are presented in Chapter 6.0. The health risk analysis is discussed further in Appendix E; the approach used in estimating health risk is dis- cussed in Appendixes D and J.

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS (continued)

EMISSION MODELS AND EMISSION ESTIMATES

APPENDIX C

APPENDIX C

EMISSION MODELS AND EMISSION ESTIMATES

The objective of Appendix C is to provide a link between

- Emission models used to estimate organic air emissions from treatment, storage, and disposal facility (TSDF) waste management units
- Model TSDF waste management unit analyses used to develop estimates of emission reductions and costs of applying emission control technologies
- The Source Assessment Model (SAM), which uses both the aforementioned to generate an estimate of nationwide TSDF organic air emissions and control costs.

This appendix provides a discussion of the mathematical models used to estimate nationwide air emissions from hazardous waste TSDF. These models represent most of the TSDF emission sources introduced in Chapter 3.0, Section 3.1. Some emission sources, such as drum crushing, are undergoing analysis at this time. The discussion of the emission models in Section C.1 includes a description of the models, a comparison of emission model estimates with results from specific field tests of TSDF waste management units, and a sensitivity analysis.

To estimate emissions with these emission models, inputs such as waste management unit surface area, waste retention time, and depth of unit are essential. Physical and chemical characteristics of the waste in the unit--such as the specific organic compounds present and their concentrations and knowledge of the presence or absence of multiple phases (e.g., separate aqueous and organic layers)--are also needed.

Use of these emission models to develop estimates of nationwide emissions requires some knowledge of the waste management unit characteristics that could affect emissions for each TSDF in the country. Given that only general information such as annual waste throughput is available for the thousands of TSDF, a model waste management unit approach was developed to facilitate emission estimates, as well as control emission reductions and control costs. Descriptions of the model units and the basis for develop-ing the range of model units characteristics are given in Section C.2.1.

As explained above, knowledge of waste physical and chemical characteristics is essential to emission estimates. Emission reductions and control costs likewise are sensitive to waste properties, so a model unit analysis to derive emission reduction and control costs also requires a definition of wastes being managed in the model waste management units. Model wastes were defined for this purpose. Section C.2.2 provides a discussion of the selection of model wastes and defines those wastes.

Lastly, in Section C.2.3, control costs and control emission reductions for a selected set of model waste management units are given in tabular form. The data contained in the table demonstrate the variations in costs and emission reductions that occur along with variations in model waste compositions and degree of emission control provided by different control technologies. These model waste management unit control costs and control emission reductions are the bases for extrapolating costs and emission reductions to nationwide estimates. Appendix D contains a discussion of the procedure for relating costs to waste throughput in each model waste management unit and then extrapolating for nationwide cost estimates via the SAM. The emission reductions expressed as a percentage of uncontrolled emissions are discussed in Chapter 4.0 and Appendix D.

C.1 EMISSION MODELS

C.1.1 <u>Description</u> of Models

The emission models that are used to estimate air emissions from TSDF processes are drawn from several different sources. These models are presented in a TSDF air emission models report that provides the basis and description of each model, along with sample calculations and comparisons of modeled emissions to measured emissions using field test data.

The emission models discussed in Chapter 3.0 are those presented in the March 1987 draft of the TSDF air emission models report.¹ Certain TSDF

emission models have been revised since that time, and a final version of the report has been released (December 1987).² The principal changes to the models involved refining the biodegradation component of the models to more accuractely reflect biologically active systems handling low organic concentration waste streams. With regard to emission model outputs, the changes, by and large, did not result in appreciable differences in the emission estimates. (Refer to Appendix D, Section D.2.4, for a more detailed discussion.)

In the emission models report, models are presented for the following TSDF management processes: surface impoundments and uncovered storage and treatment tanks; land treatment; landfills and wastepiles; and transfer, storage, and handling operations. In general, the report describes the chemical and physical pathways for organics released from hazardous wastes to the atmosphere, and it discusses their relevance to the different types of TSDF management processes and the sets of conditions that are important in emission estimation.

In the following paragraphs, the models are presented in simplified forms or in qualitative terms. For a full discussion, refer to the TSDF air emission models report.

C.1.1.1 Surface Impoundments and Uncovered Tanks.

This section presents emission models for quiescent and aerated/agitated surface impoundments and uncovered tanks. Quiescent surface impoundments where wastes flow through to other processes (i.e., storage and treatment) are addressed initially with uncovered tanks (C.1.1.1.1). Quiescent impoundments without waste flowthrough, such as disposal impoundments, are discussed in the next section (C.1.1.1.2). Aerated treatment impoundments and uncovered tanks are discussed in Section C.1.1.1.3.

C.1.1.1.1 <u>Quiescent surface with flow</u>. Emission characteristics from quiescent uncovered storage and treatment processes are similar; therefore, the same basic model was used to estimate emissions from all such processes. These waste management processes for flowthrough emission modeling include uncovered tank storage, storage surface impoundments, uncovered quiescent treatment tanks, and quiescent treatment impoundments. The modeling approach used to estimate emissions from these types of TSDF management units is based on the work of Springer et al.³ and Mackay and

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Yeun⁴ for the liquid-phase mass transfer and MacKay and Matasugu⁵ for the gas-phase mass transfer. The emission equation used is a form of the basic relationship describing the mass transfer of a volatile constituent from the opened liquid surface to the air. The model for flowthrough impound-ments and tanks assumes that the system is well-mixed and that the bulk concentration is equal to the effluent concentration. A material balance for this yields:

$$QC_{O} = KAC_{I} + QC_{I} \tag{C-1}$$

where

 QC_0 = emission rate, g/s

 $Q = volumetric flow rate, m^3/s$

 C_0 = influent concentration of organics in the waste, g/m^3

K = overall mass transfer coefficient, m/s

A = liquid surface area, m^2

 C_1 = bulk (effluent) concentration of organics, g/m^3 .

The overall mass transfer coefficient is based on:

$$\frac{1}{K} = \frac{1}{K_{L}} + \frac{1}{K_{G}K_{eq}}$$
(C-2)

where

K = overall mass transfer coefficient, m/s

K_L = liquid-phase mass transfer coefficient, m/s

 K_G = gas-phase mass transfer coefficient, m/s

Keq = equilibrium constant or partition coefficient, unitless.

C.1.1.1.2 Quiescent surface with no outlet flow. A disposal impoundment is defined as a unit that receives waste for ultimate disposal rather than for storage or treatment. This type of impoundment differs from the storage and treatment impoundments in that there is no liquid flow out of the impoundment. The calculation of the overall mass transfer coefficient is the same as that presented for quiescent surfaces with flow.

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However, the assumption that the bulk concentration is equal to the effluent concentration is not applicable here. The emission-estimating procedure differs in the calculation of the liquid-phase concentration that is the driving force for mass transfer to the air. The emission rate can be calculated as follows:

$$E = \frac{V Co}{t} [1 - exp (-KAt/V)] \qquad (C-3)$$

where

E = Emission rate, g/s

- V = Volume of the impoundment, m^3
- t = Time after disposal, s

and with the other symbols as previously defined. Reference 2 gives a detailed derivation of the above equation.

C.1.1.1.3 <u>Aerated systems</u>. Aeration or agitation in an aqueous system transfers air (oxygen) to the liquid to improve mixing or to increase biodegradation. Aerated hazardous waste management processes include uncovered, aerated treatment tanks and aerated treatment impoundments. A turbulent liquid surface in uncovered tanks and impoundments enhances mass transfer to the air. Thus, there are two significant differences between the quiescent emission model and the aerated emission model: (1) the modified mass transfer coefficient and (2) the incorporation of a biodegradation term. The calculation of the overall mass transfer coefficient for mechanically aerated systems is based on the correlations of Thibodeaux and Reinhart for the liquid and gas phases, respectively.^{6,7} The rate of biodegradation was assumed to be first order with respect to concentration based on experimental data in the form of a decay model; this is similar to the Monod model at low loadings.

A material balance around the well-mixed system yields:

$$QC_{o} = QC_{L} + K_{b}C_{L}V + KC_{L}A \qquad (C-4)$$

where

 QC_0 = emission rate, g/s

 $Q = volumetric flow rate, m^3/s$

- C_0 = influent concentration of organics in the waste, g/m³
- C_1 = bulk (effluent) concentration of organics in the waste, g/m^3
- $K_{\rm b}$ = pseudo first-order rate constant for biodegradation, 1/s
- V = system volume, m³
- K = overall mass transfer coefficient, m/s
- A = surface area, m^2 .

C.1.1.2 <u>Land Treatment</u>. Emissions from land treatment operations may occur in three distinct ways: from application of waste to the soil surface, from the waste on the soil surface before tilling, and from the soil surface after the waste has been tilled into the soil.

Short-term emissions of organics from hazardous waste lying on the soil surface prior to tilling, a result of surface application land treatment, are estimated by calculating an overall mass transfer coefficient similar to that for an oil film on a surface impoundment. The basic assumption is that mass transfer is controlled by the gas-phase resistance. The gas-phase mass transfer coefficient and the equilibrium constant are calculated from the correlation of MacKay and Matasugu⁸ and from Raoult's law, respectively.

The RTI land treatment model is used to calculate long-term emissions from waste that is mixed with the soil. This condition may exist when waste has been applied to the soil surface and has seeped into the soil, when waste has been injected beneath the soil surface, or when the waste has been tilled into the soil. In land treatment, soil tilling typically occurs regardless of the method of waste application.

The RTI land treatment emission model for long-term emissions from a land treatment unit incorporates terms that consider the major competing pathways for loss of organics from the soil; the model combines a diffusion equation for the waste vapors in the soil and a biological decay rate equation. The RTI model is based on Fick's second law of diffusion applied to a flat slab as described by Crank⁹ and includes a term to estimate biological decay assuming a decay rate that is first order with respect to waste loading in the soil. No equations are presented here because they are not easily condensed. However, these equations are described in the TSDF air emission models report. C.1.1.3 <u>Waste Fixation, Wastepiles, and Landfills</u>. Two major emission models are used in estimating emissions from landfills. Both assume that all wastes are fixed wastes and that no biological degradation takes place to reduce organic content.

One model estimates emissions from closed landfills.¹⁰ The Closed Landfill Model is used to estimate emissions from waste placed in a closed (or capped) landfill that is vented to the atmosphere and, as a special case, emissions from active landfills receiving daily earth covers. This model accounts for the escape of organics resulting from diffusion through the cap and convective loss from landfill vents resulting from barometric pumping. The closed landfill model is based primarily on the work of Farmer et al.,¹¹ who applied Fick's first law for steady-state diffusion. Farmer's equation utilizes an effective diffusion coefficient for the soil cap based on the work of Millington and Quirk.¹² The model also includes a step to estimate convective losses from the landfill. The TSDF air emission models report describes the model in detail.

The RTI land treatment model is used to estimate the air emissions from active landfills (landfills still receiving wastes) and wastepiles.¹³ As previously stated, this model is based on Fick's second law of diffusion applied to a flat slab as described by Crank, and it includes a term to estimate biological decay assuming a decay rate that is first order with respect to waste loading in the soil. A land-treatment-type model was selected for estimating emissions from open landfills and wastepiles because (1) there are a number of similarities in physical characteristics of open landfills, wastepiles, and land treatment operations, and (2) the input parameters required for the land treatment model are generally available for open landfills and wastepiles, which is not the case for some of the more theoretical models for these sources.

The emission model developed to characterize organic air emissions from uncovered wastes described in the air emissions model report was not considered appropriate for estimating emissions from waste fixation processes. However, a number of field tests have been conducted,¹⁴ and these data were used to develop an emission factor for this process.

C.1.1.4 <u>Transfer, Storage, and Handling</u>. This subsection discusses organic emission models for container loading and spills, fixed-roof tank loading and storage, dumpster storage, and equipment leaks.

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C.1.1.4.1 <u>Container loading and spills</u>. Containers can include drums, tank trucks, railroad tank cars, and dumpsters. To calculate organic emissions from loading liquid wastes into all of these containers except dumpsters, the AP-42 equation for loading petroleum liquids is applied.¹⁵ This equation was derived for tank cars and marine vessels. It is also applied to tank trucks and 0.21-m³ (55-gal) drums in this case because the loading principles are similar. (No equation has been developed exclusively for small containers such as drums.) Covered container loading emissions are based on the AP-42 equation:

$$L_{L} = \frac{12.46}{T} \text{ SMP}$$
 (C-5)

where

L_L = loading loss, 1b/1,000 gal of liquid loaded

- T = bulk temperature of liquid, K
- S = saturation factor, dimensionless
- M = molecular weight of vapor, lb/lb mol
- P = true vapor pressure of liquid, psia.

Spillage is the only other significant emission source from covered containers. An EPA study of truck transport to and from TSDF and truck emissions at TSDF terminals provided the background information necessary to estimate spillage losses during TSDF trucking, handling, and storage operations. The emission estimate for losses at a storage facility applies the same spill fraction used for drum handling, 1×10^{-4} , developed by EPA.¹⁶ The following equation estimates drum handling and storage emissions:

$$L_{s} = 10^{-4} \times T \times W_{i} \times V_{i}$$
(C-6)

where

- L_s = emissions from drum storage, Mg/yr
- T = throughput, Mg/yr
- W_i = organic weight fraction
- V_i = volatilization fraction.

Spillage emissions from tank trucks and railroad tank cars are estimated using the same equation except that the spill fraction of 10^{-5} for other types of waste movement is applied instead of the 10^{-4} spill fraction for drum handling.¹⁷ (See the TSDF air emission models report, Section 7.7.)

C.1.1.4.2 <u>Dumpster storage</u>. Emissions from open dumpster storage are estimated using a model based originally upon the work of Arnold, which was subsequently modified by Shen¹⁸ and EPA/GCA¹⁹ Corporation to characterize organic air emissions from uncovered wastes. The equation in its final form is thus presented as:

$$E_{i} = \frac{2 P_{o} MW_{i} y_{i}^{*}}{RT} \sqrt{\frac{DilU}{\pi F_{v}}}$$
(C-7)

where:

 E_{1} = emission rate of constituent of interest from the emitting surface, g/s

 P_0 = total system pressure (ambient pressure), mmHg

MW_i = molecular weight of constituent i, g/g mol

- y_i* = equilibrium mole fraction of the i-th constitutent in the gas
 phase
 - w width of the volatilizing surface perpendicular to the wind direction, cm
 - $R = ideal gas constant, 62,300 mmHg \cdot cm^3/g mol \cdot K$
 - T = ambient temperature, K
 - D_i = diffusivity of volatilizing constituent in air, cm²/s

 - U = windspeed, cm/s
 - F_v = correction factor for Fick's law

 $\pi = 3.1416.$

C.1.1.4.3 <u>Tank storage</u>. Stationary, fixed-roof tank working losses are those created by loading and unloading wastes and are estimated using AP-42, "Storage of Organic Liquids":²⁰

$$L_{w} = 1.09 \times 10^{-8} \times M_{v} \times P \times V \times K_{n} \times K_{c}$$
 (C-8)

where

 M_v = molecular weight of vapor in tank, lb/lb mol

- P = true vapor pressure at bulk liquid conditions, psia
- V = throughput, gal/yr
- $K_n = turnover factor, dimensionless$
- K_c = product factor, dimensionless.

There are also "breathing" losses for a fixed-roof tank caused by temperature and pressure changes. An existing AP-42²¹ equation is used to estimate these emissions:

$$L_{b} = 1.02 \times 10^{-5} M_{v} \left[\frac{P}{14.7 - P} \right]^{0.68} \times D^{1.73} \times H^{0.51} \times \Delta T^{0.5}$$
(C-9)
× F_p × C × K_c

where

- L_b = fixed-roof breathing loss, Mg/yr (the AP-42 constant of 2.26 x 10^{-2} is converted to 1.02 x 10^{-5} to convert lb/gal thoughput to Mg/yr)
- $M_v = molecular weight, lb/lb mol$
- P = true vapor pressure, psia
- D = tank diameter, ft
- H = average vapor space height, ft
- ΔT = average ambient diurnal temperature change, °F
- F_{D} = paint factor, dimensionless
- C = adjustment factor for small diameter tanks, dimensionless
- K_c = product factor, dimensionless.

These equations originally were developed for handling organic liquids in industries producing or consuming organic liquids, but are used here for TSDF tank storage.
C.1.1.4.4 Equipment leaks. Emissions from equipment leaks are those resulting from leaks in equipment that is used to control pressure, provide samples, or transfer pumpable organic hazardous waste. The emissions from equipment leaks in hazardous waste management are dependent on the number of pump seals, valves, pressure relief devices, sampling connections, openended lines, and the volatility of the wastes handled. The emissionestimating model used for TSDF equipment leaks is independent of the throughput, type, or size of the process unit. The TSDF equipment leak emission model is based on the Synthetic Organic Chemical Manufacturing Industries (SOCMI) emission factors developed to support standard SOCMI equipment leak emission standards.²² The input parameters required for the equipment leak emission model begin with the emission factor for the equipment pieces such as pump seals, the number of sources, and the residence time of the waste in the equipment. It was assumed that with no purge of waste from the equipment when the equipment is not in use, organics are continuously being leaked to the atmosphere. Section C.2, "Model Unit Description," explains the selection process for the number of emission sources used to develop the equipment model units.

C.1.2 Comparison of Emission Estimates with Test Results

Predictions from TSDF emission models have been compared with field test data. The following sections summarize qualitatively the comparative results that are discussed in detail in Chapter 8.0 of the TSDF air emission models report. Actual field test data are presented in Appendix F. This comparison was made with the knowledge that some uncertainty in field test precision and accuracy and the empirical nature of emission models must be considered.

C.1.2.1 <u>Surface Impoundments and Uncovered Tanks Comparison</u>. Emission test data were available for five quiescent surface impoundments. The overall mass transfer coefficients determined in these tests agreed within an order of magnitude with the overall coefficient predicted by the mass transfer correlations. Predicted emissions for these impoundments using the March 1987 version of the air emission models were higher than the measured emissions in some cases and lower in others.

When predicted emission estimates were compared to uncovered tank measured emissions, the results were mixed. For quiescent tanks, the predicted emissions were generally lower than measured emissions but agreed within an order of magnitude. For the aerated systems, the model predictions agreed well with material balance and ambient air measurements for an open aerated system.

C.1.2.2 <u>Land Treatment</u>. Field test data from four sites and one laboratory simulation were used as a basis of comparison with estimates from the land treatment emission model (see Section C.1.1.2). Estimated and measured emissions were within an order of magnitude. Estimates of both emission flux rates and cumulative emissions show results above and below measured values. Considering the potential for error in measuring or estimating values for input parameters, differences in the range of an order of magnitude are not unexpected. The emission test reports did not provide complete sets of model input data; therefore, field data averages, averages from the TSDF data base, or values identified elsewhere as representative were used as model inputs.

C.1.2.3 <u>Landfills and Wastepiles</u>. Comparisons between predicted and measured emissions from a landfill are of limited value because of lack of detailed, site-specific soil, waste, and landfill operating parameters. Typically, the composition of the landfilled waste and other required inputs to the emission models, such as the porosity of the landfill cap and the barometric pumping rate, were not included in the field test data. Comparisons of model emissions were made to measured emissions from two active landfills. The modeled emissions were found to be higher than field test measurements, in general, by factors ranging from 1 to 2 orders of magnitude. No test data were available for wastepiles.

C.1.2.4 <u>Transfer, Storage, and Handling Comparison</u>. Emission models for transfer, storage, and handling operations are based on extensive testing that led to AP-42²³ emission models and to models developed for the petroleum industry and SOCMI. The following models were developed in the petroleum industry and are applied to TSDF:

- Container loading (AP-42, Section 4.4)
- Stationary covered tank loading (AP-42, Section 4.3)
- Stationary covered tank storage (AP-42, Section 4.3).

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Equipment leak emission factors are drawn from the study of organics leak control at SOCMI facilities. Test data supporting the SOCMI equipment leak emission standard²⁴ were collected to develop these factors. An EPA study²⁵ of truck transport to and from TSDF and truck emissions at TSDF terminals provided information for spillage loss estimates. No test data were available for comparison in this TSDF effort.

C.1.3 <u>Sensitivity Analysis</u>

The emission models have been evaluated to determine which parameters have the greatest impacts on emissions. A brief discussion follows on the important model parameters for the four major types of TSDF processes: (1) surface impoundments and uncovered tanks, (2) land treatment, (3) landfills and wastepiles, and (4) transfer, storage, and handling operations. Input parameters were varied individually over the entire range of reasonable values in order to generate emission estimates. A full discussion of the emission model sensitivity analysis is presented in the TSDF air emission models report.

C.1.3.1 <u>Surface Impoundments and Uncovered Tanks</u>. Parameters to which emission estimates are most sensitive include waste concentration, retention time, windspeed for quiescent systems, fetch to depth, and biodegradation.

The emission estimates for highly volatile constituents (as defined in Appendix D, Section D.2.3.3.1) are sensitive to short retention times. For retention times on the order of several days, essentially all high volatiles are emitted. In impoundments, significant emissions of medium volatiles (as defined in Appendix D, Section D.2.3.3.1) may occur over long retention times. Henry's law constant has a direct effect on emissions of medium volatiles and a greater effect on relatively low volatile organics for which mass transfer is controlled by the gas-phase resistance.

Temperature did not affect emission estimates of the highly volatile constituents, although mass transfer for low volatile constituents was affected because of the temperature dependence of Henry's law constant. Diffusivity in air and water did not affect emission estimates.

Physical parameters of aerated systems, such as kilowatts (horsepower) and turbulent area, did affect emission estimates of medium volatiles,

although highly volatile constituents were unaffected. High volatiles are stripped out almost completely under any aerated condition.

C.1.3.2 <u>Land Treatment</u>. Air emissions from land treatment units are dependent on the chemical/physical properties of the organic constituents, such as vapor pressure, diffusivity, and biodegradation rate.

Operating and field parameters affect the emission rate, although their impact is not as great as that of constituent properties. Tilling depth, for example, plays a role; the deeper the tilling depth, the greater the time required for diffusion to the surface and therefore the greater is the potential for organics to be biodegraded. Waste concentration and waste loading (the amount of material applied to the soil per unit area) affect the emission rate on a unit area basis (emissions per unit area), but not in terms of the mass of organics disposed of (emissions per unit mass of waste).

C.1.3.3 <u>Landfills and Wastepiles</u>. Emissions from active (open) landfills, those still receiving wastes, are estimated by applying the RTI land treatment model. The sensitivity of the land treatment model to some parameters differs in its application to open landfills and wastepiles from that in land treatment operations. For application to open landfills and wastepiles, the model is sensitive to the air porosity of the solid waste, the liquid loading in the solid waste, the waste depth, the concentration of the constituent in the waste, and the volatility of the constituent under consideration. In contrast, the model is less sensitive to the diffusion coefficient of the constituent in air.

Emissions from closed landfills, those filled to design capacity and with a cap (final cover) installed, are estimated using the closed landfill model. The model is highly sensitive to the air porosity of the clay cap, which largely determines the diffusion rate through the cap. The model is also sensitive to the properties of the constituent of interest, particularly vapor pressure, Henry's law constant, and concentration. In contrast, the model exhibits relatively low sensitivity to the diffusiveness of the constituent in air, the cap thickness, and the total mass of constituent in the landfill.

C.1.3.4 <u>Transfer</u>, <u>Storage</u>, <u>and Handling Operations</u>. Equipment leak emission estimates are a function of the number of pump seals, valves,

pressure-relief valves, open-ended lines, and sampling connections selected for given process rather than throughput rate. However, equipment leak frequencies and leak rates have been shown to vary with stream volatility; emissions for high-volatility streams are greater than those for streams of low volatility.

Loading emission estimates are also sensitive to the volatility of the constituents. Both loading and spill emissions are directly proportional to throughput. The loading emission estimates for open aqueous systems, such as impoundments and uncovered tanks, are highly sensitive to the type of loading, which is either submerged or splash loading.

The fraction of waste spilled and waste throughput are used to estimate emissions resulting from spills.

C.2 MODEL TSDF WASTE MANAGEMENT UNIT ANALYSES

To evaluate the effectiveness (emission reductions) and costs of applying various types of control technologies (discussed in Chapter 4.0) to reduce emissions from waste management process units, a model unit analysis was performed. Hazardous waste management model units and model waste compositions were input to the emission models discussed above to generate uncontrolled emissions estimates from which emission reductions were computed. The model units and model waste compositions also served as the bases for estimating add-on and suppression-type control costs for each applicable control technology. Appendix H presents a discussion of the costing of add-on and suppression-type controls. The model waste compositions also provided a uniform basis for estimating the cost of treatment processes that remove organics from waste prior to land disposal. Appendix I presents a discussion of the costing of organic removal processes and hazardous waste incineration.

The development of model units, selection of model waste compositions and the results of the analyses of emission reductions and control costs are discussed in the following sections.

C.2.1 Model Unit Descriptions

Sets of model units were developed to represent the range of sizes and throughputs of hazardous waste management processes. For each model unit, parameters needed as input to the emission models were specified. The following paragraphs provide the sources of information and rationale used in developing the model units. Discussions are presented as four categories, each containing waste management processes with similar emission characteristics.

Multiple model units were developed for each waste management process to describe the nationwide range of characteristics (surface area, waste throughputs, retention time, etc.). This was determined using the frequency distributions of quantity processed, unit size, or unit area of each waste management process that were results of the Westat Survey. The distributions (expressed as weighting factors for the SAM) are presented with the tabular listing of model units in this section. The distributions were used to develop a "national average model unit" to represent each waste management process when using the Source Assessment Model. Each frequency serves as a weighting factor to approximate a national distribution of the model units defined for a particular TSDF waste management process. Appendix D, Section D.2.4.3, describes these weights and the approach to estimating nationwide organic air emissions in greater detail.

C.2.1.1 <u>Surface Impoundments and Uncovered Tanks</u>. Hazardous waste surface impoundment storage, treatment, and disposal model units are displayed in Table C-1. The ranges of surface areas and depths were based on results of the National Survey of Hazardous Waste Generators and Treatment, Storage, and Disposal Facilities Regulated Under RCRA in 1981 (Westat Survey).²⁶ The median surface area for storage and treatment impoundments in the Westat Survey was 1,500 m² and the median depth was 1.8 m. Three model unit surface areas and depths were chosen for storage and treatment impoundments, representing the medians and spanning the representative ranges of sizes for each parameter. The Westat Survey data summary for impoundments indicated that disposal impoundments generally have higher surface areas and shallower depths than storage and treatment impoundments. The model disposal impoundment was designed with the Westat Survey median surface area of 9,000 m² and the median depth of approximately 1.8 m.

Retention times in the Westat Survey ranged from 1 to 550 days, with over half of the values at 46 days or less. The storage impoundment model unit retention times, ranging from 1 to 180 days, were chosen to span the

TABLE C-1. HAZARDOUS WASTE SURFACE IMPOUNDMENT AND UNCOVERED TANK MODEL UNITS^a

Model un	it (weights, ^b %)	Parameters ^C
Surface imp	oundment storage	
SO4A Q	uiescent impoundment	Throughput - 99,000 Mg/yr Surface area - 300 m ² Depth - 0.9 m Volume - 270 m ³ Retention time - 1 d Flow rate - 3.1 L/s Temperature - 25 °C Windspeed - 4.5 m/s
SO4B Q	uiescent impoundment	Throughput - 9,800 Mg/yr Surface area - 300 m ² Depth - 0.9 m Volume - 270 m ³ Retention time - 10 d Flow rate - 0.31 L/s Temperature - 25 °C Windspeed - 4.5 m/s
(SO4A an	d B = 38.3)	
SO4C Q	uiescent impoundment	Throughput - 49,000 Mg/yr Surface area - 1,500 m ² Depth - 1.8 m Volume - 2,700 m ³ Retention time - 20 d Flow rate - 1.6 L/s Temperature - 25 °C Windspeed - 4.5 m/s
SO4D Q	uiescent impoundment	Throughput - 25,000 Mg/yr Surface area - 1,500 m ² Depth - 1.8 m Volume - 2,700 m ³ Retention time - 40 d Flow rate - 0.78 L/s Temperature - 25 °C Windspeed - 4.5 m/s
(S04C an	d D = 35.9)	
See notes a	t end of table.	(continued)

	TABLE C-1. HAZARDOUS WASTE SURFACE IMPOUNDMENT AND UNCOVERED TANK MODEL UNITS ^a (continued)					
Mode1	unit (weights, ^b %)	Parameters ^C				
Surface	impoundment storage (c	con.)				
S04E	Quiescent impoundmen	t Throughput - 120,000 Mg/yr Surface area - 9,000 m ² Depth - 3.7 m Volume 33,000 m ³ Retention time - 100 d Flow rate - 3.8 L/s Temperature - 25 °C Windspeed - 4.5 m/s				
S04F	Quiescent impoundmen	t Throughput - 67,000 Mg/yr Surface area - 9,000 m ² Depth - 3.7 m Volume - 33,000 m ³ Retention time - 180 d Flow rate - 2.1 L/s Temperature - 25 °C Windspeed - 4.5 m/s				
(S04E	and F = 25.9)					
Surface	impoundment treatment					
TO2A	Quiescent impoundmen no biodegradation	t with Throughput - 200,000 Mg/yr Surface area - 300 m ² Depth - 0.9 m Volume - 270 m ³ Retention time - 0.5 d Flow rate - 6.3 L/s Temperature - 25 °C Windspeed - 4.5 m/s				
T02B	Quiescent impoundmen no biodegradation	t with Throughput - 20,000 Mg/yr Surface area - 300 m ² Depth - 0.9 m Volume - 270 m ³ Retention time - 5 d Flow rate - 0.63 L/s Temperature - 25 °C Windspeed - 4.5 m/s				
(T02A	and B = 31.2)					

See notes at end of table.

Model unit (weights, ^b %)	Parameters ^C
Surface impoundment treatment (con.)	
TO2C Quiescent impoundment with no biodegradation	Throughput - 990,000 Mg/yr Surface area - 1,500 m ² Depth - 1.8 m Volume - 2,700 m ³ Retention time - 1 d Flow rate - 31 L/s Temperature - 25 °C Windspeed - 4.5 m/s
TO2D Quiescent impoundment with no biodegradation	Throughput - 99,000 Mg/yr Surface area - 1,500 m ² Depth - 1.8 m Volume - 2,700 m ³ Retention time - 10 d Flow rate - 3.1 L/s Temperature - 25 °C Windspeed - 4.5 m/s
(TO2C and D = 35.6)	
TO2E Quiescent impoundment with no biodegradation	Throughput - 608,000 Mg/yr Surface area - 9,000 m ² Depth - 3.7 m Volume - 33,000 m ³ Retention time - 20 d Flow rate - 19 L/s Temperature - 25 °C Windspeed - 4.5 m/s
TO2F Quiescent impoundment with no biodegradation	Throughput - 302,000 Mg/yr Surface area - 9,000 m ² Depth - 3.7 m Volume - 33,000 m ³ Retention time - 40 d Flow rate - 9.6 L/s Temperature - 25 °C Windspeed - 4.5 m/s
(TO2E and F = 33.3)	

TABLE C-1. HAZARDOUS WASTE SURFACE IMPOUNDMENT AND UNCOVERED TANK MODEL UNITS^a (continued)

See notes at end of table.

UNCOVERED	TANK MODEL UNITS ^a (continued)
Model unit (weights, ^b %)	Parameters ^C
Surface impoundment treatme	<u>ut</u> (con.)
TO2G Aerated/agitated with biodegradati	<pre>mpoundment Throughput - 200,000 Mg/yr Surface area - 300 m² Depth - 0.9 m Volume - 270 m³ Retention time - 0.5 d Flow rate - 6.3 L/s Turbulent area - 63 m² Total power - 5.6 kW (7.5 hp) Impeller power - 4.8 kW (6.4 hp) Impeller speed - 130 rad/s Impeller diameter - 61 cm 0₂ transfer - 1.83 kg/kW/h (3 lb/hp/h) 0₂ correction factor - 0.83 Biomass concentration - 0.5 g/L Temperature - 25 °C Windspeed - 4.5 m/s</pre>
TO2H Aerated/agitated with biodegradation	<pre>mpoundment Throughput - 20,000 Mg/yr Surface area - 300 m² Depth - 0.9 m Volume - 270 m³ Retention time - 5 d Flow rate - 0.63 L/s Turbulent area - 63 m² Total power - 5.6 kW (7.5 hp) Impeller power - 4.8 kW (6.4 hp) Impeller speed - 130 rad/s Impeller diameter - 61 cm O₂ transfer - 1.83 kg/kW/h (3 lb/hp/h) O₂ correction factor - 0.83 Biomass concentration - 0.5 g/L Temperature - 25 °C Windspeed - 4.5 m/s</pre>
(TO2G and H = 31.2)	

TABLE C-1. HAZARDOUS WASTE SURFACE IMPOUNDMENT AND UNCOVERED TANK MODEL UNITS^a (continued)

See notes at end of table.

TABLE	C-1.	HAZA	RDOUS	WASTE	SURFACE	E IMPOUNDMENT	AND
	UNCOVE	ERED	TANK	MODEL	UNITSa	(continued)	

Model	unit (weights, ^b %)	Parameters ^C
Surface i	mpoundment treatment (con.)	
T021	Aerated/agitated impoundment with biodegradation	Throughput - 990,000 Mg/yr Surface area - 1,500 m ² Depth - 1.8 m Volume - 2,700 m ³ Retention time - 1 d Flow rate - 31 L/s Turbulent area - 370 m ² Total power - 56 kW (75 hp) Impeller power - 48 kW (64 hp) Impeller speed - 130 rad/s Impeller diameter - 61 cm O ₂ transfer - 1.83 kg/kW/h (3 lb/hp/h) O ₂ correction factor - 0.83 Biomass concentration - 0.5 g/L Temperature - 25 °C Windspeed - 4.5 m/s
T02J	Aerated/agitated impoundment with biodegradation	Throughput - 99,000 Mg/yr Surface area - 1,500 m ² Depth - 1.8 m Volume - 2,700 m ³ Retention time - 10 d Flow_rate - 3.1 L/s Turbulent area - 370 m ² Total power - 56 kW (75 hp) Impeller power - 48 kW (64 hp) Impeller speed - 130 rad/s Impeller diameter - 61 cm O ₂ transfer - 1.83 kg/kW/h (3 lb/hp/h) O ₂ correction factor - 0.83 Biomass concentration - 0.5 g/L Temperature - 25 °C Windspeed - 4.5 m/s
(T02I	and J = 35.6)	

See notes at end of table.

(continued)

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Mode1	unit (weights, ^b %)	Parameters ^C
Surface	<pre>impoundment treatment (con.)</pre>	
T02K	Aerated/agitated impoundment with biodegradation	Throughput - 608,000 Mg/yr Surface area - 9,000 m ² Depth - 3.7 m Volume - 33,000 m ³ Retention time - 20 d Flow rate - 19 L/s Turbulent area - 2,700 m ² Total power - 671 kW (900 hp) Impeller power - 574 kW (770 hp) Impeller speed - 130 rad/s Impeller diameter - 61 cm 0 ₂ transfer - 1.83 kg/kW/h (3 lb/hp/h) 0 ₂ correction factor - 0.83 Biomass concentration - 0.5 g/L Temperature - 25 °C Windspeed - 4.5 m/s
TO2L	Aerated/agitated impoundment with biodegradation	Throughput - 302,000 Mg/yr Surface area - 9,000 m ² Depth - 3.7 m Volume - 33,000 m ³ Retention time - 40 d Flow rate - 9.6 L/s Turbulent area - 2,700 m ² Total power - 671 kW (900 hp) Impeller power - 574 kW (770 hp) Impeller speed - 130 rad/s Impeller diameter - 61 cm 02 transfer - 1.83 kg/kW/h (3 lb/hp/h) 02 correction factor - 0.83 Biomass concentration - 0.5 g/L Temperature - 25 °C Windspeed - 4.5 m/s
(T02K	and L = 33.3)	
Surface i	mpoundment disposal	
D83A	Quiescent impoundment with no biodegradation (100)	Throughput - 32,000 Mg/yr Surface area - 9,000 m ² Depth - 1.8 m Volume - 16,000 m ³ Retention time - 183 d Temperature - 25 °C Windspeed - 4.5 m/s

TABLE C-1. HAZARDOUS WASTE SURFACE IMPOUNDMENT AND UNCOVERED TANK MODEL UNITS^a (continued)

Mode1	unit (weights, ^b	%)	Parameters ^C
Storage	tanks		
S02F	Uncovered tank	(37.7)	Throughput - 110 m ³ /yr Surface area - 2.3 m ² Depth - 2.4 m Volume - 5.7 m ³ Retention time - 18.3 d Temperature - 25 °C Windspeed - 4.5 m/s
S02G	Uncovered tank	(0q)	Throughput - 60.4 m ³ /yr Surface area - 13 m ² Depth - 2.4 m Volume - 30.2 m ³ Retention time - 183 d Temperature - 25 °C Windspeed - 4.5 m/s
S02H	Uncovered tank	(32.3)	Throughput - 1,100 m ³ /yr Surface area - 13 m ² Depth - 2.4 m Volume - 30.2 m ³ Retention time - 9.9 d Temperature - 25 °C Windspeed - 4.5 m/s
S02I	Uncovered tank	(17.8)	Throughput - 3,300 m ³ /yr Surface area - 26 m ² Depth - 2.7 m Volume - 76 m ³ Retention time - 8.3 d Temperature - 25 °C Windspeed - 4.5 m/s
S02J	Uncovered tank	(12.2)	Throughput - 17,000 m ³ /yr Surface area - 65 m ² Depth - 12 m Volume - 790 m ³ Retention time - 17.4 d Temperature - 25 °C Windspeed - 4.5 m/s

TABLE C-1. HAZARDOUS WASTE SURFACE IMPOUNDMENT AND UNCOVERED TANK MODEL UNITS^a (continued)

See notes at end of table.

TABLE	C-1.	HAZA	RDOUS	WASTE	SURFAC	Ε	IMPOUNDMENT	AND
	UNCOVE	RED	TANK	MODEL	UNITSa	(c	ontinued)	

Mode1	unit (weights, ^b %)	Parameters ^C			
Treatment	tanks				
T01A	Uncovered quiescent tank (28.3)	Throughput - 11,000 Mg/yr Surface area - 13 m ² Depth - 2.4 m Volume - 30.2 m ³ Retention time - 24 h Flow rate - 0.35 L/s Temperature - 25 °C Windspeed - 4.5 m/s			
T01B	Uncovered quiescent tank (21.8)	Throughput - 28,000 Mg/yr Surface area - 26 m ² Depth - 2.7 m Volume - 76 m ³ Retention time - 24 h Flow rate - 0.88 L/s Temperature - 25 °C Windspeed - 4.5 m/s			
TOIC	Uncovered quiescent tank (50.0)	Throughput - 290,000 Mg/yr Surface area - 65 m ² Depth - 12 m Volume - 800 m ³ Retention time - 24 h Flow rate - 9.2 L/s Temperature - 25 °C Windspeed - 4.5 m/s			
TO1G	Uncovered aerated/agitated tank (78.3)	Throughput - 240,000 Mg/yr Surface area - 27 m ² Depth - 4 m Volume - 108 m ³ Retention time - 4 h Flow rate - 7.5 L/s Turbulent area - 14 m ² Total power - 5.6 kW (7.5 hp) Impeller power - 4.8 kW (6.4 hp) Impeller speed - 130 rad/s Impeller diameter - 61 cm O ₂ transfer - 1.83 kg/kW/h (3 lb/hp/h) O ₂ correction factor - 0.83 Biomass concentration - 4.0 g/L Temperature - 25 °C Windspeed - 4.5 m/s			

Model unit (weights, ^b %)	Parameters ^C
TO1H Uncovered aerated/agitated tank (21.8)	Throughput - 2,800,000 Mg/yr Surface area - 430 m ² Depth - 3.7 m Volume - 1,600 m ³ Retention time - 5 h Flow rate - 88 L/s Turbulent area - 250 m ² Total power - 89.5 kW (120 hp) Impeller power - 38 kW (51 hp) Impeller speed - 130 rad/s Impeller diameter - 61 cm O ₂ transfer - 1.83 kg/kW/h (3 lb/hp/h) O ₂ correction factor - 0.83 Biomass concentration - 4.0 g/L Temperature - 25 °C Windspeed - 4.5 m/s

TABLE C-1. HAZARDOUS WASTE SURFACE IMPOUNDMENT AND UNCOVERED TANK MODEL UNITS^a (continued)

^aHazardous waste surface impoundment and uncovered tank model units represent the ranges of uncovered, quiescent, and aerated surface storage, treatment, and disposal surface impoundments and storage and treatment tanks in the hazardous waste management industry.

^bBecause design characteristics and operating parameters (surface area, waste throughputs, detention times, and so on) were generally not available for all treatment, storage, and disposal facilities (TSDF), weighting factors were developed to approximate the nationwide distribution of model units defined for a particular TSDF waste management process. The weighting factors are based on the considerable statistical data available in the 1981 EPA survey of hazardous waste generators and TSDF conducted by Westat, Inc. (Westat Survey). For example, results of this survey were used to determine the national distribution of sizes of storage tanks (storage volume), surface impoundments (surface area), and landfills (surface area and depth). For further information on weighting factors, refer to Appendix D, Sections D.2.4.3 and D.2.5.

CModel unit parameters may not be equal (e.g., Throughput ≠ Volume x Turnovers) because of rounding.

^dThis model unit was weighted 0% because SO2H also has the same surface area. This avoids double weighting of a unit size.

reasonable range of values, based on knowledge of the operation of impoundments that are representative of the industry. Retention times greater than 180 days were not used to estimate emissions because organics are emitted from a surface impoundment within 180 days. The retention time in treatment impoundments was expected to be less than the retention times in storage impoundments. Two design manuals listed typical retention times for aerated impoundments as 7 to 20 days²⁷ and 3 to 10 days.²⁸ Retention times bounding these ranges were chosen for the quiescent and aerated/ agitated impoundments. No data were available concerning disposal surface impoundment retention times; therefore, the disposal surface impoundment was selected with a 6-month retention time or the time within which the organics would be emitted. Volume for each surface impoundment model unit was calculated from area and depth; the retention time yielded the flow rate.

Two meteorological parameters required for the emission models were temperature and windspeed. The parameters chosen were a standard temperature of 25 °C and a windspeed of 4.5 m/s. These standard values were evaluated by estimating emissions from surface impoundments for windspeed/ temperature combinations at actual sites based on their frequency of occurrence. Over a 1-yr period, the results from site-specific data on windspeed and temperature were not significantly different from the results using the standard values. Consequently, the standard values were judged adequate for the model units.

With regard to the aerated/agitated treatment impoundments, one source, Metcalf and Eddy,²⁹ suggests a range of 0.37 to 0.75 kW/28.3 m³ (0.5 to 1.0 hp/1,000 ft³) for mixing. However, more power may be needed to supply additional oxygen or to mix certain treatment solutions. Information obtained through site visits to impoundments indicates power usage as high as 2.6 kW/28.3 m³ (3.5 hp/1,000 ft³) at a specific TSDF impoundment.³⁰ For this analysis, a midrange value of 0.56 kW/28.3 m³ (0.75 hp/1,000 ft³) from Metcalf and Eddy was used to generate estimates of the power required for mixing in each model unit.

Data from Reference 31 indicate that an aerator with a 56-kW (75-hp) motor and a 61-cm-diameter propeller turning at 126 rad/s would agitate a volume of 660 m^3 . Agitated volumes were estimated by holding propeller

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diameter and rotation constant and treating agitated volume as being proportional to power. The agitated volume divided by depth yielded the agitated surface area, which was modeled as turbulent area. Typical values were chosen for the oxygen transfer rating of the aerator and the oxygen transfer correction factor. A value of 1.83 kg $O_2/kW/h$ (3.0 lb $O_2/hp/h$) was chosen for the oxygen transfer rating from a range of 1.76 to 1.83 (2.9 to 3.0).³² A value of 0.83 was used for the correction factor from a typical range of 0.80 to 0.85.³³ For estimating the impeller power, an 85-percent efficient transfer of power to the impeller was used.³⁴ A midrange biomass concentration for continuous stirred tank reactors was chosen from Reference 35. A biomass concentration of 0.5 g/L was chosen as an estimate, representing an upper bound on the design guidelines in References 36 and 37.

Table C-1 also presents uncovered, quiescent and aerated/agitated hazardous waste treatment tank model units. According to responses to the 1981 EPA survey of hazardous waste generators and TSDF conducted by Westat, Inc. (Westat Survey), which were examined by the GCA Corporation, 38 there are four sizes of tanks that best represent the waste management industry: 5.3 m³, 30 m³, 76 m³, and 800 m³. The quiescent storage and treatment tank model units were sized accordingly.

Retention times were chosen to span the retention times commonly used by wastewater treatment tank units.³⁹ The retention times and tank capacities were used to arrive at flow rates for the model units. These flow rates are comparable to those found in the EPA survey conducted by Westat for medium and large wastewater treatment tanks. The remaining physical parameters for quiescent treatment tanks were chosen on the basis of engineering judgment. Meteorological conditions cited for quiescent and aerated tanks represent standard annual (temperature and windspeed) and daily (temperature change) values.

For aerated/agitated treatment tanks, the agitation parameters for the aerated, biologically active tanks were derived as described previously for aerated/agitated surface impoundments.

C.2.1.2 <u>Land Treatment</u>. Table C-2 displays hazardous waste land treatment model units. Model unit parameters were based primarily on a data base developed by EPA⁴⁰ from site visits and contacts with State,

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Model unit (weights, ^b %)	Parameters
D81A (NA)	Throughput - 360 Mg/yr Land area ^C - 1 ha Oil content of waste - 10% Soil air porosity - 0.5 Soil total porosity - 0.61 Tilling depth - 20 cm Temperature - 25 °C
D81B (NA)	Throughput - 1,800 Mg/yr Land area ^C - 5 ha Oil content of waste - 10% Soil air porosity - 0.5 Soil total porosity - 0.61 Tilling depth - 20 cm Temperature - 25 °C
D81C (NA)	Throughput - 5,400 Mg/yr Land area ^C - 15 ha Oil content of waste - 10% Soil air porosity - 0.5 Soil total porosity - 0.61 Tilling depth - 20 cm Temperature 25 °C
D81D (NA)	Throughput - 27,000 Mg/yr Land area ^C - 75 ha Oil content of waste - 10 ⁵ Soil air porosity - 0.5 Soil total porosity - 0.61 Tilling depth - 20 cm Temperature - 25 °C

TABLE C-2. HAZARDOUS WASTE LAND TREATMENT MODEL UNITS^a

NA = Not applicable.

^aHazardous waste land treatment model units represent the range of land treatment processes in the hazardous waste management industry.

^bWeighting factors were developed for each unit to represent each waste management process when estimating nationwide emissions. These factors are based on frequency distributions of quantity processed, unit size, or unit area that were results of the Westat Survey, approximately a national distribution of model units.

^CWaste is applied only to one-half of the land area based on knowledge of industry practice, allowing the undisturbed area to stabilize.

regional, and industry sources and supplemented by information from recent literature. These values were chosen as reasonably representative of average or typical practices currently used at land treatment operations. The data base showed annual throughput varying from about 2 Mg/yr to about 400,000 Mg/yr with a median value of 1,800 Mg/yr. The area of land treatment sites ranged from less than 1 ha to about 250 ha with a median value of 5 ha. These two median values were selected to develop the model units. The data base showed tilling depth varying from 15 cm to one case of 65 cm, with most being in the range of 15 to 30 cm. The single most frequently reported tilling depth was 20 cm, which was selected as a typical value. This value is in line with values of 15 to 30 cm reported in another study.⁴¹ The data base showed oil content of the waste streams varying from about 2 to 50 percent, with a median value of about 12 percent and model value of 10 percent. The 10-percent figure was selected as typical.

Very little soil porosity information has been identified. One study reported measured values of soil porosity in a land treatment plot as ranging from 43.3 to 65.1 percent⁴² with an average value of about 50 percent. The literature did not specify whether this soil porosity represented total soil porosity or soil air porosity. Therefore, these literature values were chosen to represent soil air porosity. Total soil porosity included the air porosity and the space occupied by oil and water within soil. One field study reported measured values of both total porosity and air-filled porosity.⁴³ Measured values of total soil porosity ranged from 54.7 to 64.8 percent, with an average value of 60.7 percent. Measured values of air-filled porosity ranged from 27.4 to 46.9 percent, with an average of 37.2 percent. Thus, the value of 61 percent for total soil porosity was chosen to be a representative value based on the median measured total soil porosity of 60.7 percent. A value of 50 percent was used as a default for air porosity.

C.2.1.3 <u>Waste Fixation, Wastepiles, and Landfills</u>. As part of the landfill operation, fixation model units were developed. Table C-3 shows hazardous waste fixation pit model units. The fixation pit has a length of 6 m, with a width of 3 m and a depth of 3 m. These dimensions represent reasonable estimates of industry practice based on observations at actual sites. The duration of the fixation operation was taken to be a maximum of

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Model unit (weights, ^b %)	Parameters
Fixation pit	
Fixation pit A (46.0)	Throughput - 17,000 Mg/yr fixed waste Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Fixed waste density - 1.8 g/cm ³ Number of pits - 1 Pit surface dimensions - 3x6 m Pit depth - 3 m Number of batches - 160/yr Windspeed - 4.5 m/s Wind direction - along length of pit Temperature - 25 °C Duration of fixation - 2 h
Fixation pit B (14.9)	Throughput - 120,000 Mg/yr fixed waste Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Fixed waste density - 1.8 g/cm ³ Number of pits - 2 Pit surface dimensions - 3x6 m Pit depth - 3 m Number of batches - 1,200/yr Windspeed - 4.5 m/s Wind direction - along length of pit Temperature - 25 °C Duration of fixation - 2 h

TABLE C-3. HAZARDOUS WASTE FIXATION PIT, WASTEPILE STORAGE, AND LANDFILL DISPOSAL MODEL UNITS^a

See notes at end of table.

(continued)

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Model unit (weights, ^b %)	Parameters
Fixation pit (con.)	
Fixation pit C (39.2)	Throughput - 170,000 Mg/yr fixed waste Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Fixed waste density - 1.8 g/cm ³ Number of pits - 4 Pit surface dimensions - 3x6 m Pit depth - 3 m Number of batches - 1,600/yr Windspeed - 4.5 m/s Wind direction - along length of pit Temperature - 25 °C Duration of fixation - 2 h
Wastepile	
SO3D Wastepile (41.5)	Throughput - 17,000 Mg/yr Surface area - 46 m ² Average height - 0.77 m Volume - 36 m ³ Waste density - 1.8 g/cm ³ Turnovers - 300/yr Retention time - 1.2 days Temperature - 25 °C Windspeed - 4.5 m/s Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Total porosity fixed waste - 0.50 Air porosity fixed waste - 0.25 Biomass concentration - 0 g/cm ³

TABLE C-3. HAZARDOUS WASTE FIXATION PIT, WASTEPILE STORAGE, AND LANDFILL DISPOSAL MODEL UNITS^a (continued)

See notes at end of table.

Model un	it (weights, ^b %)	Parameters
Wastepil	e (con.)	
S03E	Wastepile (36.0)	Throughput - 120,000 Mg/yr Surface area - 470 m ² Average height - 1 m Volume - 460 m ³ Waste density - 1.8 g/cm ³ Turnovers - 140/yr Retention time - 2.6 days Temperature - 25 °C Windspeed - 4.5 m/s Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Total porosity fixed waste - 0.50 Air porosity fixed waste - 0.25 Biomass concentration - 0 g/cm ³
S03F	Wastepile (22.5)	Throughput - 170,000 Mg/yr Surface area - 14,000 m ² Average height - 4 m Volume - 57,000 m ³ Waste density - 1.8 g/cm ³ Turnovers - 1.6/yr Retention time - 220 days Windspeed - 4.5 m/s Temperature - 25 °C Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Total porosity fixed waste - 0.50 Air porosity fixed waste - 0.25 Biomass concentration - 0 g/cm ³

TABLE C-3. HAZARDOUS WASTE FIXATION PIT, WASTEPILE STORAGE, AND LANDFILL DISPOSAL MODEL UNITS^a (continued)

See notes at end of table.

(continued)

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TABLE C-3. HAZARDOUS WASTE FIXATION PIT, WASTEPILE STORAGE, AND LANDFILL DISPOSAL MODEL UNITS ^a (continued)			
Model un	it (weights, ^b %)		Parameters
Landfill	disposal		
D80D	Active landfill	(46.0)	Surface area - 0.4 ha Depth of waste - 1.1 m Degree of filling - half full Ambient temperature - 25 °C Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Total porosity of fixed waste - 0.50 Air porosity of fixed waste - 0.25 Biomass conc 0 g/cm ³
D80E	Active landfill	(14.9)	Surface area - 1.4 ha Depth of waste - 2.3 m Degree of filling - half full Ambient temperature 25 °C Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Total porosity of fixed waste - 0.50 Air porosity of fixed waste - 0.25 Biomass conc 0 g/cm ³
D80F	Active landfill	(39.2)	Surface area - 2 ha Depth of waste - 2.3 m Degree of filling - half full Ambient temperature - 25 °C Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Total porosity of fixed waste - 0.50 Air porosity of fixed waste - 0.25 Biomass conc 0 g/cm ³

See notes at end of table.

Model unit (weights, ^b %)		Parameters	
Landfill disposal (con.)			
D80G Closed landfill	(46.0)	Surface area - 0.4 ha Waste bed thickness - 2.3 m Cap thickness - 110 cm Total porosity of cap - 0.41 Air porosity of cap - 0.08 Temperature beneath cap - 15 °C Typical barometric pressure - 1.01 x 10 ⁻⁵ Pa (1,013 mbar) Daily barometric pressure drop - 4.0 x 10 ⁻⁸ Pa (4 mbar) Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Air porosity of fixed waste - 0.25 Biomass conc 0 g/cm ³	
D80H Closed landfill	(14.9)	Surface area - 1.4 ha Waste bed thickness - 4.6 m Cap thickness - 110 cm Total porosity of cap - 0.41 Air porosity of cap - 0.08 Temperature beneath cap - 15 °C Typical barometric pressure - 1.01 x 10 ⁻⁵ Pa (1,013 mbar) Daily barometric pressure drop - 4.0 x 10 ⁻⁸ Pa (4 mbar) Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Air porosity of fixed waste - 0.25 Biomass conc 0 g/cm ³	

TABLE C-3. HAZARDOUS WASTE FIXATION PIT, WASTEPILE STORAGE, AND LANDFILL DISPOSAL MODEL UNITS^a (continued)

See notes at end of table.

TABLE C-3. HAZARDOUS WASTE FIXATION PIT, WASTEPILE STORAGE, AND LANDFILL DISPOSAL MODEL UNITS^a (continued)

Model unit (weights, ^b %)	Parameters	
Landfill disposal (con.)		
D80I Closed landfill (39.2)	Surface area - 2 ha Waste bed thickness - 4.6 m Cap thickness - 110 cm Total porosity of cap - 0.41 Air porosity of cap - 0.08 Temperature beneath cap - 15 °C Typical barometric pressure - 1.01 x 10 ⁻⁵ Pa (1,013 mbar) Daily barometric pressure drop - 4.0 x 10 ⁻⁸ Pa (4 mbar) Liquid/fixative - 1 cm ³ liquid + fixative = 1 cm ³ fixed waste Air porosity of fixed waste - 0.25 Biomass conc 0 g/cm ³	

^aHazardous waste fixation pit, wastepile storage, and landfill disposal model units represent the ranges of these processes in the hazardous waste management industry.

^bBecause design characteristics and operating parameters (surface area, waste throughputs, detention times, and so on) were generally not available for all treatment, storage, and disposal facilities (TSDF), weighting factors were developed to approximate the nationwide distribution of model units defined for a particular TSDF waste management process. The weighting factors are based on the considerable statistical data available in the 1981 EPA survey of hazardous waste generators and TSDF conducted by Westat, Inc. (Westat Survey). For example, results of this survey were used to determine the national distribution of sizes of storage tanks (storage volume), surface impoundments (surface area), and landfills (surface area and depth). For further information on weighting factors, refer to Appendix D, Sections D.2.4.3 and D.2.5. 2 h, based on operating practice at one site.⁴⁴ The wind direction was assumed to be along the length of the pit, and a standard temperature of 25 °C and windspeed of 4.5 m/s were used.

Hazardous waste wastepile storage model units are presented in Table C-3 as part of landfill operations. The wastepile surface areas were designed to represent the range of basal areas reported in the Westat Survey, with 470 m² being an approximately midrange value. For modeling purposes, the pile was assumed to be flat. The heights were based on Westat information and engineering judgment. The wastepile retention times were derived from the landfill volumes, the wastepile volumes, and the landfill filling time (to capacity) of 1 yr. With regard to the waste characteristics, the waste density represents a fixed two-phase aqueous/ organic waste. The fixation industry indicated that waste liquid, when combined with fixative, may increase in volume by up to 50 percent, 45, 46, 47 depending on the specific combination of waste fixative. However, because of the inherent variability in the fixation process and the lack of real data on volume changes, this analysis did not incorporate a waste volume change during fixation. Measurements⁴⁸ performed on various types of fixed waste yielded a broad range of total porosities; therefore, 50 percent was chosen as a reasonable estimate of total porosity. A 25-percent air porosity value was inferred from measurements of total porosity and moisture content.⁴⁹ The toxic property of the waste can inhibit the biological processes and prevent biogas generation. 50 Therefore, the waste biomass concentration is 0 g/cm^3 .

Table C-3 also provides hazardous waste landfill disposal model units. The active landfill surface areas represent the range of surface areas reported in the Westat Survey. A standard temperature of 25 °C was chosen for the model.

As with active landfills, the closed landfill surface areas and depths were based on Westat Survey data. The landfill cap was considered to be composed of compacted clay. The cap thickness of 110 cm represents the average of extremes in thickness of clay caps (61 cm to 180 cm) reported in site studies.⁵¹ The value used for air porosity of the clay cap is 8 percent, while the total porosity is 41 percent. These values were computed based on reasonable physical properties and level of compaction for

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compacted clay.⁵² The temperature beneath the landfill cap was estimated at 15 °C, which represents the temperature of shallow ground water at a mid-latitude U.S. location.⁵³ A constant temperature was used. The landfill is exposed to a nominal barometric pressure of 1.01×10^{-5} Pa (1,013 mbar), which represents an estimate of the annual average atmospheric pressure in the United States.⁵⁴ Barometric pumping was estimated for the landfill using a daily pressure drop from the nominal value of 4.0 $\times 10^{-8}$ Pa (4 mbar). The 4.0 $\times 10^{-8}$ Pa (4 mbar) value represents an estimate of the annual average diurnal pressure drop.⁵⁵ The closed landfill model units were designed to contain fixed or solid wastes. As explained previously for hazardous waste wastepile model units, biomass concentration was taken to be 0 g/cm³ for active and closed landfills.

C.2.1.4 Transfer, Storage, and Handling. Table C-4 presents model units for loading and storing hazardous waste in containers and covered tanks and for sources of equipment leaks during waste transfer. The EPA's Hazardous Waste Data Management System was reviewed⁵⁶ to select the most representative volumetric capacities of container storage (drums and dumpsters) facilities. Based on this review, two model drum storage facilities were developed: an onsite or private TSDF with a 21-m³ capacity processing 42 m^3 annually, and a commercial TSDF with a 40-m^3 capacity processing 460 m^3 annually. The Westat Survey indicated that waste containers are typically in the form of 0.21-m³ (55-gal) drums.⁵⁷ Therefore, these model capacities would hold 100 and 180 drums, respectively, at any one time. A telephone conversation with a dumpster vendor⁵⁸ identified two basic capacities of small roll-off containers: 3.1 m³ and 4.6 m³. The 3.1-m³ rolloff, which turns over 6.1 m^3 annually, was selected as a model. It has a length of 1.9 m, width of 1.5 m, and height of 1.2 m. In addition, an average annual ambient temperature of 25 °C and an average windspeed of 4.5 m/s were used.

Containers (drums, tank trucks, and rail tank cars) were considered to be splash-loaded for emission-estimating purposes because data were not available to determine whether one loading method predominates. This loading method creates larger quantities of organic vapors and increases the saturation factor of each volatile compound within the container. A saturation factor is a dimensionless quantity that represents the expelled

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Model unit (weights, ^b %)		Parameters
Container storage		
S01A	Drum storage (66.1)	Throughput - 42 m ³ /yr Volume - 0.21 m ³ /drum Capacity - 100 drums Turnovers - 2/yr Spill fraction - 10-4 Volatilization fraction - 0.5
S01B	Drum storage (33.9)	Throughput - 460 m ³ /yr Volume - 0.21 m ³ /drum Capacity - 180 drums Turnovers - 12/yr Spill fraction - 10 ⁻⁴ Volatilization fraction - 0.5
S01C	Dumpster storage (O)	Throughput - 6 m ³ /yr Windspeed - 4.5 m/s Temperature - 25 °C Length - 1.9 m Width - 1.5 m Height - 1.2 m Turnovers - 2/yr
Container	loading	
Drum 1	oading (NA)	Throughput - 42 m ³ /yr Volume - 0.21 m ³ /drum Bulk temperature - 25 °C Saturation factor (dimensionless) - 1.45 Number of loadings - 200/yr
Drum la	oading (NA)	Throughput - 460 m ³ /yr Volume - 0.21 m ³ /drum Bulk temperature - 25 °C Saturation factor (dimensionless) - 1.45 Number of loadings - 2,200/yr
Tank tr	ruck loading (NA)	Throughput - 105 m ³ /yr Volume - 27 m ³ Bulk temperature - 25 °C Saturation factor (dimensionless) - 1.45 Number of loadings - 4/yr

See notes at end of table.

Model unit (weights, ^b %)	Parameters
Container loading (con.)	
Tank truck loading (NA)	Throughput - 420 m ³ /yr Volume - 27 m ³ Bulk temperature - 25 °C Saturation factor (dimensionless) - 1.45 Number of loadings - 16/yr
Rail tank car loading (NA)	Throughput - 450 m ³ /yr Volume - 110 m ³ Bulk temperature - 25 °C Saturation factor (dimensionless) - 1.45 Number of loadings - 4/yr
Rail tank car loading (NA)	Throughput - 1,800 m ³ /yr Volume - 110 m ³ Bulk temperature - 25 °C Saturation factor (dimensionless) - 1.45 Number of loadings - 16/yr
<u>Storage tanks</u>	
SO2A Covered tank (37.7)	Throughput - 110 m ³ /yr (30,000 gal/yr) Volume - 5.7 m ³ (1,500 gal) Diameter - 1.7 m (5.6 ft) Adjustment for small diameter (dimensionless) - 0.26 Height - 2.4 m (8 ft) Average vapor space height - 1.2 m (4 ft) Average diurnal temperature change - 11 °C Paint factor (dimensionless) - 1 Turnovers - 20/yr

See notes at end of table.

Model ur	nit (weights, ^b %)	Parameters
Storage	tanks (con.)	
S02B	Covered tank (O ^C)	Throughput - 60.4 m ³ /yr (16,000 gal/yr) Volume - 30.2 m ³ (8,000 gal) Diameter - 4 m (13 ft) Adjustment for small diameter (dimensionless) - 0.65 Height - 2.4 m (8 ft) Average vapor space height - 1.2 m (4 ft) Average diurnal temperature change - 11 °C Paint factor (dimensionless) - 1 Turnovers - 2/yr
S02C	Covered tank (32.3)	Throughput - 1,100 m ³ /yr (290,000 gal/yr) Volume - 30.2 m ³ (8,000 gal) Diameter - 4 m (13 ft) Adjustment for small diameter (dimensionless) - 0.65 Height - 2.4 m (8 ft) Average vapor space height - 1.2 m (4 ft) Average diurnal temperature change - 11 °C Paint factor (dimensionless) - 1 Turnovers - 37/yr
S02D	Covered tank (17.8)	Throughput - 3,300 m ³ /yr (870,000 gal/yr) Volume - 76 m ³ (20,000 gal) Diameter - 5.8 m (19 ft) Adjustment for small diameter (dimensionless) - 0.86 Height - 2.7 m (9 ft) Average vapor space height - 1.4 m (4.6 ft) Average diurnal temperature change - 11 °C Paint factor (dimensionless) - 1 Turnovers - 44/yr

See notes at end of table.

Model unit (weights, ^b %)	Parameters			
Storage tanks (con.)				
SO2E Covered tank (12.2)	Throughput - 17,000 m ³ /yr (4,500,000 gal/yr) Volume - 790 m ³ (210,000 gal) Diameter - 9.1 m (30 ft) Adjustment for small diameter (dimensionless) - 1 Height - 12 m (39 ft) Average vapor space height - 6 m (20 ft) Average diurnal temperature change - 11 °C Paint factor (dimensionless) - 1 Turnovers - 21/yr			
<u>Treatment tanks</u> d				
TOID Covered quiescent tank (28.3) Throughput - 11,000 Mg/yr Volume - 30.2 m ³ Diameter - 4 m Adjustment for small diameter (dimensionless) - 0.65 Height - 2.4 m Average vapor space height - 1.2 m Average diurnal temperature change - 11 °C Paint factor (dimensionless) - 1 Retention time - 24 h			
TOIE Covered quiescent tank (21.8)) Throughput - 28,000 Mg/yr Volume - 76 m ³ Diameter - 5.8 m Adjustment for small diameter (dimensionless) - 0.86 Height - 2.7 m Average vapor space height - 1.4 m Average diurnal temperature change - 11 °C Paint factor (dimensionless) - 1 Turnovers - 365/yr			

See notes at end of table.

Model unit (weights, ^b %)	Parameters
Treatment tanks (con.)	
T01F Covered quiescent tank (50.0	<pre>) Throughput - 290,000 Mg/yr Volume - 790 m³ Diameter - 9.1 m Adjustment for small diameter (dimensionless) - 1 Height - 12 m Average vapor space height - 6 m Average diurnal temperature change - 11 °C Paint factor (dimensionless) - 1 Turnovers - 365/yr</pre>
Equipment leaks	
Equipment leak model unit A ^e (NA)	Pump seals - 5 Valves - 165 Sampling connections - 9 Open-ended lines - 44 Pressure relief valves - 3

NA = Not applicable.

^aHazardous waste transfer, storage, and handling operation model units represent the ranges of these operations in the hazardous waste management industry.

- ^bBecause design characteristics and operating parameters (surface area, waste throughputs, detention times, and so on) were generally not available for all treatment, storage, and disposal facilities (TSDF), weighting factors were developed to approximate the nationwide distribution of model units defined for a particular TSDF waste management process. The weighting factors are based on the considerable statistical data available in the 1981 EPA survey of hazardous waste generators and TSDF conducted by Westat, Inc. (Westat Survey). For example, results of this survey were used to determine the national distribution of sizes of storage tanks (storage volume), surface impoundments (surface area), and landfills (surface area and depth). For further information on weighting factors, refer to Appendix D, Sections D.2.4.3 and D.2.5.
- ^CThe model unit was weighted 0% because SO2C also has the same volumetric capacity. This avoids double-weighting of a unit size.
- ^dLoading emissions from covered quiescent treatment tanks are estimated in the same manner as loading emissions from covered storage tanks.
- ^eEquipment leak model units B and C were not specified in terms of equipment counts. Emission estimates and control costs were calculated on the basis of model unit A equipment counts, and emission and control costs for model units B and C were factored from these estimates.

vapors fractional approach to saturation and accounts for the variations observed in emission rates from the different unloading and loading methods.⁵⁹ A saturation factor of 1.45 was selected for the emission estimates, based on previous documentation of splash-loading petroleum liquids.^{60,61} Typical capacities for containers were selected, and 25 °C was considered the annual average ambient operating temperature.

Table C-4 presents covered, hazardous waste tank storage and quiescent treatment model units. The tank sizes were based on Westat Survey information, as has been explained previously for open hazardous waste quiescent treatment tank model units in Section C.2.1.1. (The Westat Survey did not distinguish between storage and treatment tanks.) Turnovers per year were selected based on volumes of waste processed as reported in Westat⁶² and the Hazardous Waste Data Management System.⁶³ The remaining parameters were chosen, based on documented information and engineering judgment, to represent hazardous waste tank storage processes. Meteorological conditions used represent standard temperature (25 °C) and daily average temperature change (11 °C).

Table C-4 also provides hazardous waste transfer, handling, and loading (THL) operation model units to estimate emissions from equipment leaks. The equipment leak model unit A was obtained from the benzene fugitives emissions promulgation background information document⁶⁴ and was used as the baseline to develop equipment leak model units B and C. Equipment leak model units B and C were not specified in terms of equipment counts and, therefore, are not presented in Table C-4. Emission estimates and control costs were calculated on the basis of model unit A equipment counts, and emissions and control costs for model units B and C were factored from these estimates. Although the emission estimating model for equipment leaks (essentially the emission factor) is independent of throughput, it was necessary to account for throughput when applying the model units to a TSDF to estimate emissions. TSDF may treat, store, or dispose of large volumes of waste by one management process. Rather than assume that only one very large process unit (and, in turn, one fugitive model unit) is operated, the throughput of the process is divided by the throughput of its average model process unit, thus simulating the presence of multiple smaller process units. This estimates the number of average model process

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units operating at the TSDF, and one equipment leak model unit is then applied to each average model process unit to estimate emissions from equipment leaks.

C.2.2 Model Wastes

A set of model waste compositions was developed to provide a uniform basis for emission control, emission reductions, and cost estimation for the model waste management units. The model wastes were used as a necessary step preliminary to generating process designs, mass balances, and cost estimates for removal of organics and incineration devices. Table C-5 lists the model waste compositions. These model wastes also were used to develop control costs and control efficiencies by waste form for add-on and suppression-type controls, as well as organic removal devices. However, it should be pointed out that, to the extent possible, the compositions and quantities of actual waste streams processed at the existing facilities were used to estimate nationwide TSDF emissions and the emission reductions resulting from the control strategies.

The waste stream compositions in Table C-5 were selected to be representative of the major hazardous waste types containing organics.⁶⁶ One EPA study using the Waste Environmental Treatment (WET) data base⁶⁷ categorized organic-containing waste streams into major classes and evaluated pretreatment options for these wastes. That study categorized organiccontaining wastes according to the following waste classes:⁶⁸

- Organic liquids
- Aqueous organics (up to 20 percent organics)
- Dilute aqueous wastes (less than 2 percent organics)
- Organic sludges
- Aqueous/organic sludges.

Other data bases are available for specific industries, 69 but comprehensive waste stream listings for all domestic wastes are not available. Based on the known physical and chemical forms of organic-containing wastes, the following six generic waste stream types were selected for evaluation of organic removal processes, incinerators, and add-on and suppression-type controls:

Waste form	Organic content	Water content, wt %	Solid content, wt %
Dilute aqueous-1	Ø.25% ethyl chloride Ø.15% benzene	99.6	Ø
Dilute aqueous-2	0.007% vinyl chloride 0.007% methylene chloride 0.007% pyridine 0.007% acrylonitrile 0.007% phenol 0.007% o-cresol	99.96	Ø
Dilute aqueous-3	0.007% benzene 0.007% cumene 0.007% acetone 0.007% ethylacetate 0.007% 1-butanol 0.007% o-cresol	99.96	Ø
Two-phase aqueous/organic	20% chloroform 20% 1.2 dichlorobenzene	59	1
Organic liquid	30% benzene 30% naphthalene 39% phenol	Ø	1
Organic sludge/slurry	25% benzene 25% dichlorobenzene 25% naphthalene 25% hexachlorobenzene	Ø	Ø
Aqueous sludge/slurry	10% dibutylphthalate 2.5% 1-hexanol 2.5% chloroform	65	20 (Inorganic)
Organic-containing solid	1% acetonitrile	15	84 (Inorganic)

TABLE C-5. MODEL WASTE COMPOSITIONS^a

^aThe waste compositions were defined to provide bases for estimating the effectiveness and associated costs of controlling organic emissions from hazardous waste management units and of removing organics from waste streams. These waste compositions are defined as models only and do not necessarily represent real waste streams. Specific chemical properties were used in the cost exercise. These properties are listed for the majority of chemicals in Appendix D, Table D-10. Properties of the remaining chemicals are provided in Reference 65.

- Dilute aqueous wastes
- Organic liquids
- Organic sludge/slurry
- Aqueous sludge/slurry
- Two-phase aqueous/organic
- Organic-containing solids.

For each generic waste type, specific chemical compositions were next defined so that material/energy balances and costs could be calculated. Chemical compositions were chosen that represent the properties of hazardous waste, but they may not represent specific constituents. In general, compositions were specified that are:

- Representative of the generic waste stream type, i.e., that include the major organic chemical classes of environmental importance (e.g., chlorinated organics, aromatics)
- Composed of chemicals representing a range of physical and chemical properties, based on Henry's law, biodegradability, and vapor pressure
- Physically and chemically realistic (e.g., a two-phase aqueous/organic waste that in fact forms two phases at the proposed composition)
- Readily characterized by available physical and chemical property data required for the treatment or control system process designs (e.g., vapor-liquid equilibrium compositions).

Three different waste compositions were selected to represent dilute aqueous wastes. The goal in developing alternative dilute aqueous compositions (specifically dilute aqueous-2 and dilute aqueous-3) was to define waste streams that would tend to produce a broad range of costs to treat by steam stripping.⁷⁰ The choice of compounds was based on an engineering judgment that the overall cost of steam stripping a dilute aqueous waste (including residual treatment costs) is affected by the halogen content of the waste.

To validate the criterion of being physically and chemically realistic, small samples of most of the selected generic waste streams were
prepared. However, the physical and chemical properties (e.g., vaporliquid equilibrium compositions) needed for the material and energy balances have not been verified experimentally. Many organic-containing wastes are complex multicomponent mixtures. Trace levels of certain compounds (not examined in this study) could significantly affect the properties of a particular waste stream. However, the chosen waste compositions are generally suitable for developing design and cost information for treatment and control processes.

C.2.3 <u>Summary of Model Unit Analysis of Emission Reductions and Control</u> <u>Costs</u>

The model unit analysis was conducted to provide a basis for estimating the effectiveness (achievable emission reductions) and associated costs of controlling organic air emissions from TSDF hazardous waste management In the model unit analysis, control costs (both capital and units. annualized) and achievable emission reductions were determined for a matrix of (1) TSDF model units (e.g., covered storage tanks, guiescent uncovered treatment tanks, waste fixation operations, and open landfills), (2) waste forms (e.g., aqueous sludges, organic liquids, and dilute aqueous wastes), and (3) control technologies (e.g., suppression controls such as tank covers, add-on controls such as thin-film evaporators or steam strippers). The cost and emission reduction data generated in the analysis were then used to develop the control technology and cost file used for estimating nationwide impacts for alternative TSDF control strategies. This file provides control device efficiencies, emission reductions, and control costs according to waste form for each emission control technology that is applicable to a waste management process.

Table C-6 presents a summary of the results of the model unit analysis in terms of uncontrolled emission estimates, emission reductions, and control costs for the various model hazardous waste management units and organic removal processes. This model unit analysis includes only compatible combinations of model waste forms and model unit (or organic removal process). Incompatible combinations of waste form and model unit (or organic removal process) were not analyzed; e.g., an organic-containing solid waste would not be treated in a tank or treated by steam stripping.

C - 200 Drums/yr - 5 50 -1 40 c 40 c 60 urry 40 ganic 40	TORAGE (S01A) - 200 Drums/yr Aqueous 50 0.00033 0 Sludge 40 0.000083 0.0 Dilute 40 0.000083 0.0 Aqueous-1 40 0.0022 0.0022 Drganic 60 0.0027 0.0027 Sludge/Slurry 40 0.000017 0.000017	0.00031 \$43,4 0000079 \$43,4 0.0021 \$43,4 0.0026 \$43,4 0.0026 \$43,4 .000016 \$43,4	460 \$18,300 460 \$18,300 460 \$18,300 460 \$18,300 460 \$18,300 \$18,300 \$18,300 \$18,300 \$18,300
- 200 Drums/yr - 5 50 -1 40 c 40 c 60 urry 40 ganic 40	TORAGE (S01A) - 200 Drums/yr Aqueous 50 0.00033 0 Sludge 40 0.000083 0.0 Dilute 40 0.000083 0.0 Aqueous-1 40 0.0022 0.0022 Drganic 60 0.0027 0.0027 Sludge/Slurry 40 0.000017 0.000017	0.00031 \$43,4 0000079 \$43,4 0.0021 \$43,4 0.0026 \$43, .000016 \$43,	460 \$18,300 460 \$18,300 460 \$18,300 460 \$18,300 460 \$18,300 460 \$18,300
5 50 -1 40 c 40 c 60 urry 40 ganic 40	Aqueous Sludge500.000330Dilute Aqueous-1400.00000830.0Drganic Liquid400.00220.0022Organic Sludge/Slurry600.0027Two-Phase Aqueous/Organic400.000017	0.00031 \$43,4 0000079 \$43,4 0.0021 \$43,4 0.0026 \$43,4 0.0026 \$43,4 .000016 \$43,4	460 \$18,300 460 \$18,300 460 \$18,300 460 \$18,300 460 \$18,300 460 \$18,300
-1 40 c 40 c 60 urry 40 ganic 40	Dilute400.00000830.0Aqueous-1400.0022Drganic400.0022Liquid600.0027Sludge/Slurry51Two-Phase400.00017Aqueous/Organic0.00017	0.0021 \$43, 0.0021 \$43, 0.0026 \$43, .000016 \$43,	460 \$18,300 460 \$18,300 460 \$18,300 460 \$18,300
c 40 c 60 urry se 40 ganic	Organic 40 0.0022 Liquid 0.0027 Sludge/Slurry 40 0.00017 0. Two-Phase 40 0.000017 0.	0.0021 \$43,4 0.0026 \$43, .000016 \$43,	460 \$18,300 460 \$18,300 460 \$18,300
c 60 urry se 40 ganic	Organic 60 0.0027 Sludge/Slurry Two-Phase 40 0.000017 0. Aqueous/Organic	0.0026 \$43, .000016 \$43,	460 \$18,300
se 40 ganici	Two-Phase 40 0.000017 0. Aqueous/Organic	.000016 \$43,	460 \$18.300
		-	1
~ 2200 Drues/yr 15 550	TORAGE (SO1B) - 2200 Drums/yr Aqueous 560 0.0036 Sludge	0.0034 \$43,	460 \$18,300
450	Bilute 450 0.000091 0.	.000086 \$43,	460 \$18,300
ic 440	Organic 440 0.024 Liquid	0.022 \$43,	460 \$18,300
ic 610 Iurry	Organic 610 0.030 Sludge/Slurry	0.028 \$43,	460 \$18,300
ise 440 'ganic'	Two-Phase 440 0.00018 Aqueous/Organic:	0.00017 \$43,	,460 \$18,300
501C) - 3.4 m^3 (TER STORAGE (SOIC) - 3.4 m^3 (120 ft^3) Dumpster vol	use	
	Aqueous 16 0.72 1 Sludge 1	0.71	\$150 \$64
us 16		0.0485	\$150 \$72
	Aqueous/Or IER STORAGE (S Aqueou Sludge	ganic: 501C) - 3.4 m^3 (120 ft^3) Dumpster vol 15 16 0.72 16 0.049 16 0.049	Ganic: GOIC) - 3.4 m ³ (120 ft ³) Dumpster volume IS 16 0.72 0.71 ic 24 0.049 0.0485

See notes at end of table.

EMISSION CONTROL	MODEL Waste type	ANNUAL Throughput (Mg/yr)	C: UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL Annual Costs
COVERED	STORAGE TANK (SO)	TAN	IK STORAGE			
Internal	Aqueous	140	0.0045	0.004	\$4,820	\$1,520
ficating Roof	; Sludge ; Dilute ; Aqueous-1	110	0.083	0.061	\$4,820	\$1,520
	l Organic Liquid	110	0.017	0.014	\$4,820	\$1,520
	Organic Sludge/Slurry	130	0.043	0.035	\$4,820	\$1,520
	: Two~Phase Aqueous/Organic	131	0.035	0.027	\$4,820	\$1,520

Vent to Existing	Aqueous Sludge	140	0.0045	0.004	\$1,600	\$320
Control Device	Dilute Aqueous-1	110	0.083	0.079	\$1,600	\$320
	Organic Liquid	110	0.017	0.016	\$1,600	\$320
	Organic Sludge/Slurry	130	0.043	0.041	\$1,600	\$320
	i Two-Phase Aqueous/Organic	131	0.035	0.033	\$1,600	\$320
Vent to Carbon	Aqueous Sludge	140	0.0045	0.004	\$1,050	\$2,220
Canisters	Dilute Aqueous-1	110	0.083	0.079	\$1,050	\$5,330
	Organic Liquid	110	0.017	0.016	^ 1,050	\$2,800
	Organic Sludge/Slurry	130	0.043	0.041	\$1,050	\$3,520
	¦ Two-Phase Aqueous/Organic	131	0.035	0.033	\$1,050	\$3,500
101111111111111111	****************	\$2373 <i>33</i> 232222	26233333333333333333	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		*********

See notes at end of table.

					1922222222222222222 1	**********
b Emission Control	MODEL Waste type	ANNUAL Throughput (Mg/yr)	UNCONTROLLED ENISSIONS (Mg/yr)	d ; EMISSION 1 REDUCTION 1 (Mg/yr) 1	TDTAL CAPITAL INVESTMENT	TOTAL Annual Costs
		TAI	K STORAGE			
COVERED	STORAGE TANK (SO)	2B) - 8,000 gi	al tank			
Internal Floating	Aqueous Sludge	70	0.013	0.011	\$8,400	\$2,600
KOGt	Dilute Aqueous-1	60	0.180	0.133	\$8,400	\$2,600
	Organic Liquid	60	0.0465	0.038	\$8,400	\$2,600
	Organic Sludge/Slurry	70	0.114	0.093	\$8,400	\$2,600
	l Two-Phase Aqueous/Organic	70	0.075	0.058	\$8,400	\$2,600
Vent to	Aqueous	70	0.013	0.012	\$1,600	\$320
Control Device	Dilute Aqueous-1	60	0.180	0.171	\$1,600	\$320
	Organic Liquid	60	0.0465	0.044	\$1,600	\$320
	Organic Sludge/Slurry	70	0.114	0.108	\$1,600	\$320
	Two-Phase Aqueous/Organic	70	0.075	0.071	\$1,600	\$320
Vent to Carbon	Aqueous Sludge	70	0.013	0.012	\$1,050	\$2,220
Canisters	Dilute Aqueous-1	60	0.180	0.171	\$1,050	\$8,720
	Drganic Liquíd	60	0.0465	0.044	\$1,050	\$3,520
	Organic Sludge/Slurry	70	0.114	0.108	\$1,050	\$6,100
	i Two∸Phase ¦Aqueous/Organic	70	0.075	0.071	\$1,050	\$4,810

See notes at end of table.

EMISSION Control	MODEL Waste type	ANNUAL THROUGHPUT (Mg/yr)	C UNCONTROLLED EMISSIONS (Hg/yr)	d EMISSION REDUCTION (Hg/yr)	TOTAL Capital Investment	TOTAL Annual Costs
		TAN	IK STORAGE	18282		
COVERED	STORAGE TANK (SOZ	2C) - 8,000 ga	il tank			
Internal Floating	Aqueous Sludge	1,380	0.045	0.037	\$8,400	\$2,600
RUOT	Dilute Aqueous-1	1,120	0.813	0.602	\$8,400	\$2,600
	Organic Liquid	1,090	0.167	0.137	\$8,400	\$2,600
	Organic Sludge/Slurry	1,320	0.424	0.348	\$8,400	\$2,600
	Two-Phase Aqueous/Organic	1,300	0.342	0.267	\$8,400	\$2,600
Vent to Existing	Aqueous Sludge	1,380	0.045	0.043	\$1,600	\$320
Control Device	Dilute Aqueous-1	1,120	0.813	0.772	\$1,600	\$320
	Organic Liquid	1,090	0.167	0.159	\$1,600	\$320
	Organic Słudge/Slurry	1,320	0.424	0.403	\$1,600	\$320
	Two-Phase Aqueous/Organic	1,300	0.342	0.325	\$1,600	\$320
Yent to Carbon Canisters	Aqueous Sludge	1,380	0.045	0.043	\$1,050	\$3,530
	Dilute Aqueous-1	1,120	0.813	0.772	\$1,050	\$34,130
	Organic Liquid	1,090	0.167	0.159	\$1,050	\$8,730
	Organic Sludge/Slurry	1,320	0.424	0.403	\$1,050	\$18,500
	Two-Phase Aqueous/Organic	1,300	0.342	0.325	\$1,050	\$15,220

See notes at end of table.

EMISSION CONTROL	NODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d : EMISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL Annual Costs
		TAI	K STORAGE			
COVERED	STORAGE TANK (SO	2D) - 20,000	gal tank			
Internal Floating	Aqueous Siudge	4,100	0.117	0.096	\$11,380	\$3,500
KOOT	Dilute Aqueous-1	3,300	2.12	1.569	\$11,380	\$3,500
	Organic Liquid	3,200	0.437	0.358	\$11,380	\$3,500
	Organic Sludge/Slurry	3,900	1.11	0.910	\$11,380	\$3,500
	i Two-Phase Aqueous/Organic	3,900	0.891	0.695	\$11,380	\$3,500
Vent to Existing	Aqueous Sludge	4,100	0.117	0.111	\$1,600	\$320
Control Device	Dilute Aqueous-1	3,300	2.12	2.014	\$1,600	\$320
	Organic Liquid	3,200	0.437	0.415	\$1,600	\$320
	Organic Sludge/Slurry	3,900	1.11	1.055	\$1,600	\$320
	i Two-Phase Aqueous/Organic	3,900	0.891	0.846	\$1,600	\$320
Vent to Carbon	Aqueous Sludge	4,100	0.117	0.111	\$1,050	\$8,110
Canisters	Dilute Aqueous-1	3,300	2.12	2.014	\$1,050	\$87,600
	Drganic Liquid	3,200	0.437	0.415	\$1,050	\$20,480
	Organic Sludge/Slurry	3,900	1.11	1.055	\$1,050	\$47,240
	, Two . Phase ¦Aqueous/Organic	3,900	0.891	0.846	\$1,050	\$38,750

See notes at end of table.

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EMISSION Control	MODEL Waste Type	ANNUAL THROUGHPUT (Mg/yr)	C UNCONTROLLED Emissions (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TOTAL CAPITAL INVESTMENT	TOTAL Annual Costs
_		TAN	K STORAGE			
COVERED	STORAGE TANK (SO2	2E) - 210,000	gal tank			
Internal Floating Pool	Aqueous Sludge	20,520	0.678	0.556	\$19,660	\$6,100
NUUT	Dilute Aqueous-1	16,660	12.35	9.139	\$19,660	\$6,100
	Organic Liquíd	16,260	2.53	2.075	\$19,660	\$6,100
	Organic Sludge/Slurry	19,640	6.43	5.273	\$19,660	\$6,100
	Two-Phase Aqueous/Organic	19,300	5.19	4.048	\$19,660	\$6,100
Vent to Existing	Aqueous Sludge	20,520	0.678	0.644	\$1,600	\$11,080
Control Device	Dilute Aqueous-1	16,660	12.35	11.733	\$1,600	\$15,660
	Organic Liquid	16,260	2.53	2.403	\$1,600	\$13,170
	Organic Sludge/Slurry	19,640	6.43	6.108	\$1,600	\$13,160
	Two-Phase Aqueous/Organic	19,300	5.19	4.931	\$1,600	\$13,700
Vent to Fixed Bed	Aqueous Sludge	20,520	0.678	0.644	\$72,300	\$40,000
Adsorber	Dilute Aqueous-1	16,660	12.35	11.733	\$72,300	\$50,480
	Organic Liquid	16,260	2.53	2.403	\$72,300	\$40,000
	Organic Sludge/Slurry	19,640	6.43	6.108	\$72,300	\$40,260
	Two-Phase Aqueous/Organic	19,300	5.19	4.931	\$72,300	\$40,140

See notes at end of table.

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EMISSION Control	MODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	CUNCONTROLLED EMISSIONS (Mg/yr)	d ENISSION REDUCTION (Ng/yr)	TOTAL Capital Investment	TOTAL Annual Costs
		TA	K STORAGE			
QUIESCEN	T UNCOVERED STOR	AGE TANK (SO2)	F) - 1,500 gal 1	tank		
Fixed Roof	Aqueous Sludge	140	1.5	1.496	\$3,790	\$760
	i Dilute Aqueous-1	110	0.36	0.28	\$3,790	\$760
	Organic Liquid	110	26	25.98	\$3,790	\$760
	Organic Sludge/Slurry	130	31	30.96	\$3,790	\$760
	Two-Phase Aqueous/Organic	130	0.39	0.36	\$3,790	\$760
Internal Floating	Aqueous Sludge	140	1.5	1.499	\$7,330	\$1,870
Roof (+ fixed roof)	Dilute Aqueous-1	110	0.36	0.34	\$7,330	\$1,870
	Organic Liquid	110	26	25.996	\$7,330	\$1,870
	Organic Sludge/Slurry	130	31	30.99	\$7,330	\$1,870
	Two-Phase Aqueous/Organic	130	0.39	0.383	\$7,330	\$1,870
Vent to Existing Control	Aqueous Sludge	140	1.5	1.4998	\$5,370	\$1,080
Device (+ fixed roof)	Dilute Aqueous-1	110	0.36	0.356	\$5,370	\$1,080
	Organic Liquid	110	26	25.999	\$5,370	\$1,080
	Drganic Sludge/Slurry	130	31	30.998	\$5,370	\$1,080
	Two-Phase Aqueous/Organic	130	0.39	0.389	\$5,370	\$1,080
Vent to Carbon	Aqueous Sludge	140	1.5	1.4998	\$4,840	\$2,980
<pre>Canister { + fixed roof}</pre>	Dilute Aqueous-1	110	0.36	0.356	\$4,840	\$6,090
	organic Liquid	110	26	25.999	\$4,840	\$3,560
	Organic Sludge/Slurry	130	31	30.998	\$4,840	\$4,280
	Two-Phase Aqueous/Organic	130	0.39	0.389	\$4,840	\$4,260
\$ 23 32 232585 2	1222222222222222222			********	**=====================================	

See notes at end of table.

b Emission Control	MODEL Waste type	ANNUAL THROUGHPUT (Mg/yr)	C UNCONTROLLED Emissions (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL ANNUAL COSTS
		TAP	IK STORAGE			
QUIESCEN	I UNCOVERED STOR	AGE TANK (SOZE	3) - 8,000 gal 1	tank		
Fixed Roof	Aqueous Sludge	70	1.4	1,39	\$9,500	\$1,880
	Dilute Aqueous-1	60	0.24	0.06	\$9,500	\$1,880
	Organic Liquid	60	24	23.95	\$9,500	\$1,880
	Organic Sludge/Slurry	70	29	28.89	\$9,500	\$1,880
	; Two-Phase Aqueous/Organic	70	0.23	0.16	\$9,500	\$1,880
			[
Internal Floating	Aqueous Sludge	70	1.4	1.398	\$16,450	\$4,000
Koof (+ fixed roof)	; Dilute Aqueous-1	60	0.24	0.19	\$16,450	\$4,000
	Organic Liquid	60	24	23.99	\$16,450	\$4,000
	Organic Sludge/Slurry	70	29	28.98	\$16,450	\$4,000
	; 1 Two-Phase Aqueous/Organic	70	0.23	0.21	\$16,450	\$4,000
Vent to Existing	: Aqueous Sludge	70	1.4	1.3995	\$11,080	\$2,200
Device (+ fixed	Dilute Aqueous-1	60	0.24	0.23	\$11,080	\$2,200
r00t)	i Organic Liquid	60`	24	23.998	\$11,080	\$2,200
	Organic Sludge/Slurry	70	29	28.99	\$11,080	\$2,200
	i 1 Two-Phase 1Aqueous/Organic	70	0.23	0.227	\$11,080	\$2,200
Vent to Carbon	l Aqueous I Sludge	70	1.4	1.3995	\$10,550	\$4,100
Canister (+ fixed roof)	¦ } Dilute } Aqueous-1	60	0.24	0.23	\$10,550	\$10,600
	l Organic Liquid	60	24	23.998	\$10,550	\$5,460
	 Organic Sludge/Slurry	70	29	28.99	\$10,550	\$7,980
	l Two-Phase Aqueous/Organic	70	0.23	0.227	\$10,550	\$6,690

See notes at end of table.

b Emission Control	MODEL Waste Type	ANNUAL Throughput (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSION REDUCTION {Mg/yr}	TOTAL Capital Investment	TOTAL Annual Costs
		TAI	IK STORAGE			
QUIESCEN	T UNCOVERED STOR	IGE TANK (SO2)	i) - 8,000 gal t	ank		
Fixed Roof	Aqueous Sludge	1,380	11	10.96	\$9,500	\$1,880
	Dilute Aqueous-1	1,120	3.2	2.4	\$9,500	\$1,880
	Organic Liquid	1,090	217	216.8	\$9,500	\$1,880
	Organic Sludge/Slurry	1,320	243	242.6	\$9,500	\$1,880
	Two-Phase Aqueous/Organic	1,300	3.6	3.3	\$9,500	\$1,880
					1	
Internal Floating	Aqueous Sludge	1,380	11	10.99	\$16,450	\$4,000
Koot (+ fixed roof)	Dilute Aqueous-1	1,120	3.2	3.0	\$16,450	\$4,000
	Drganic Liquid	1,090	217	216.96	\$16,450	\$4,000
	Organic Sludge/Slurry	1,320	243	242.9	\$16,450	\$4,000
	; Two-Phase Aqueous/Organic	1,300	3.6	3.53	\$16,450	\$4,000
Vent to	Aqueous	1,380	11 1	10.998	\$11,080	\$2,200
Existing Control	Sludge Diluba	1 120	7.0	7.1/	611 000	
{ + fixed roof}	Aqueous-1	1,120	3.2	3.16	\$11,080	\$2,200
	Organic Liquid	1,090	217	216.99	\$11,080	\$2,200
	Organic Sludge/Slurry	1,320	243	242.98	\$11,080	\$2,200
	Two-Phase Aqueous/Organic	1,300	3.6	3.59	\$11,080	\$2,200
Vent to Carbon	Aqueous Sludge	1,380	11	10.998	\$10,550	\$5,410
<pre>canister { + fixed roof}</pre>	Dilute Aqueous-1	1,120	3.2	3.16	\$10,550	\$36,010
	i Orĝanic Liquid	1,090	217	216.99	\$10,550	\$10,610
	Organic Sludge/Slurry	1,320	243	242.98	\$10,550	\$20,380
	Two-Phase Aqueous/Organic	1,300	3.6	3.59	\$10,550	\$17,100

See notes at end of table.

EMISSION Control	MODEL Waste type	ANNUAL THROUGHPUT (Mg/yr)	c UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TDTAL CAPITAL INVESTMENT	TOTAL ANNUAL COSTS
		TAI	NK STORAGE			
QUIESCENT	UNCOVERED STOR	AGE TANK (SO2)	I) - 20,000 gal			
	Aqueous Siudge	4,100	24	23.9	\$14,800	\$2,930
	Dilute Aqueous-1	3,300	8.1	6.0	\$14,800	\$2,930
	Organic Liquid	3,200	514	513.6	\$14,800	\$2,930
	Organic Sludge/Slurry	3,900	586	584.9	\$14,800	\$2,930
	Two-Phase Aqueous/Organic	3,900	9.7	8.8	\$14,800	\$2,930
		{	;	:		
Internal Floating	Aqueous Sludge	4,100	24	23.98	\$24,420	\$5,860
(+ fixed roof)	Dilute Aqueous-1	3,300	8.1	7.6	\$24,420	\$5,860
	Organic Liquíd	3,200	514	513.9	\$24,420	\$5,860
	Organic Sludge/Slurry	3,900	586	585.8	\$24,420	\$5,860
********	, Two-Phase Aqueous/Organic	3,900	9.7	9.5	\$24,420	\$5,860
Vent to Existing	Aqueous Sludge	4,100	24	23.995	\$16,380	\$3,250
Device (+ fixed	Dilute Aqueous-1	3,300	8.1	8.0	\$16,380	\$3,250
, דעט ז	Organic Liquid	3,200	514	513.98	\$16,380	\$3,250
	Organic Sludge/Slurry	3,900	586	585.9	\$16,380	\$3,250
	Two-Phase Aqueous/Organic	3,900	9.7	9.66	\$16,380	\$3,250
Vent to Carbon	Aqueous Sludge	4,100	24	23.995	\$15,850	\$11,040
Canister (+ fixed roof)	Dilute Aqueous-1	3,300	8.1	8.0	\$15,850	\$90,530
	Drganic Liquid	3,200	514	513.98	\$15,850	\$23,410
	Organic Sludge/Slurry	3,900	586	585.9	\$15,850	\$50,170
	Two-Phase Aqueous/Organic	3,900	9.7	9.66	\$15,850	\$41,680

See notes at end of table.

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EMISSION CONTROL	MODEL WASTE TYPE	ANNUAL THROUGHPUT (Mg/yr)	c UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL Annual Costs
		TAI	IK STORAGE			
QUIESCEN	T UNCOVERED STOR	AGE TANK (SO2	() - 210,000 gal	tank		
Fixed Roof	Aqueous Sludge	20,520	70	69.3	\$26,040	\$5,200
	Dilute Aqueous-1	16,660	30	17.7	\$26,040	\$5,200
	Organic Liquid	16,260	1,730	1,727	\$26,040	\$5,200
	Organic Sludge/Slurry	19,640	1,960	1,954	\$26,040	\$5,200
	Two-Phase Aqueous/Organic	19,300	41	35.8	\$26,040	\$5,200
	!	1		. 1		
Internal Floating	Aqueous Sludge	20,520	70	69.9	\$40,560	\$9,500
Koot (+ fixed roof)	Dilute Aqueous-1	16,660	30	26.8	\$40,560	\$9,500
	Organic Liquid	16,260	1,730	1,729.5	\$40,560	\$9,500
	Organic Sludge/Slurry	19,640	1,960	1958.9	\$40,560	\$9,500
	Two-Phase Aqueous/Organic	19,300	41	39.9	\$40,560	\$9,500
Vent to Existing	Aqueous Sludge	20,520	70	69.97	\$27,620	\$5,600
Device (+ fixed	Dilute Aqueous-1	16,660	30	29.4	\$27,620	\$5,600
ruuri	Organic Liquid	16,260	1,730	1,729.9	\$27,620	\$5,600
	Organic Sludge/Slurry	19,640	1,960	1959.7	\$27,620	\$5,600
	Two-Phase Aqueous/Organic	19,300	41	40.7	\$27,620	\$5,600
Vent to Fixed Bed	Aqueous Sludge	20,520	70	69.97	\$98,340	\$45,200
Adsorber (+ fixed	Dilute Aqueous-1	16,660	30	29.4	\$98,340	\$55,6BO
FOUTI	Organic Liquid	16,260	1,730	1,729.9	\$98,340	\$45,200
	Organic Sludge/Slurry	19,640	1,960	1959.7	\$98,340	\$45,460
	Two-Phase Aqueous/Organic	19,300	41	40.7	\$98,340	\$45,340

See notes at end of table.

EMISSION Control	MODEL Waste type	ANNUAL Throughput (Ng/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d ENISSION REDUCTION (Mg/yr)	TOTAL CAPITAL INVESTMENT	TOTAL Annual Costs
			#ASTE	EPILE STORAGE		
WASTEPIL	E COVER (S03D) -	1300 ft^3 was	ste volume			
Wastepile Cover-30 mil	Aqueous Sludge	17,000	16.0	15.95	\$650	\$2,500
זער	Two-Phase Aqueous/Organic	17,000	10.0	4.9	\$650	\$2,500
Thin-Film Evaporator	Aqueous Sludge	17,000	16.0	15.7	\$1,400,000	\$460,000
Steam Stripping	i Two-Phase Aqueous/Drganic	17,000	10.0	4.7	\$86,000	\$76,000
WASTEPIL: Wastepile	: Aqueous	120.000	139.7	139.3	\$6.480	\$4.700
WASIEPILi Wastanila		120 000	! 139.7 !	। । रफ्र र	\$4 490	*4 700
WASTEPIL Wastepile Cover-30 mil HDPE	Aqueous Sludge Two-Phase Aqueous/Organic	120,000	139.7	139.3 49.3	\$6,480 \$6,480	\$4,700 \$4,700
WASIEPIL Wastepile Cover-30 mil HDPE Thin-Eilm	Aqueous Sludge Two-Phase Aqueous/Organic	120,000 120,000	139.7 100.0	139.3 49.3	\$6,480 \$6,480	\$4,700 \$4,700
WASIEPIL Wastepile Cover-30 mil HDPE Thin-Film Evaporator	Aqueous Sludge Two-Phase Aqueous/Organic Sludge	120,000 120,000 120,000	139.7 100.0 139.7	139.3 49.3 137.3	\$6,480 \$6,480 \$10,200,000	\$4,700 \$4,700 \$3,290,000
WASIEPIL Wastepile Cover-30 mil HDPE Thin-Film Evaporator Steam Stripping	Aqueous Sludge Two-Phase Aqueous/Organic Sludge Two-Phase Aqueous/Organic	120,000 120,000 120,000 120,000	139.7 100.0 139.7 100.0	139.3 49.3 137.3 62.7	\$6,480 \$6,480 \$10,200,000 \$609,000	\$4,700 \$4,700 \$3,290,000 \$536,000
WASIEPIL Wastepile Cover-30 mil HDPE Thin-Film Evaporator Steam Stripping WASTEPIL	Aqueous Sludge Two-Phase Aqueous/Organic Sludge Two-Phase Aqueous/Organic Aqueous/Organic	120,000 120,000 120,000 120,000 2,010,000 ft	139.7 100.0 139.7 100.0	139.3 49.3 137.3 62.7	\$6,480 \$6,480 \$10,200,000 \$609,000	\$4,700 \$4,700 \$3,290,000 \$536,000
WASIEPIL Wastepile Cover-30 mil HDPE Thin-Film Evaporator Steam Stripping WASTEPIL Wastepile Cover-30 mil HDPF	Aqueous Sludge Two-Phase Aqueous/Organic Sludge Two-Phase Aqueous/Organic E COVER (S03F) - Aqueous Sludge	120,000 120,000 120,000 120,000 120,000 2,010,000 ft ⁻ 170,000	139.7 100.0 139.7 100.0 ^3 waste volume 457.0	139.3 49.3 137.3 62.7 455.6	\$6,480 \$6,480 \$10,200,000 \$609,000 \$197,300	\$4,700 \$4,700 \$3,290,000 \$536,000 \$62,000
WASTEPIL Wastepile Cover-30 mil HDPE Thin-Film Evaporator Stripping WASTEPIL Wastepile Cover-30 mil HDPE	Aqueous Sludge Two-Phase Aqueous/Organic Sludge Two-Phase Aqueous/Organic E COVER (SO3F) - Aqueous Sludge Two-Phase Aqueous/Organic	120,000 120,000 120,000 120,000 120,000 120,000 ft ⁻ 170,000	139.7 100.0 139.7 100.0 3 waste volume 457.0 390.0	139.3 49.3 137.3 62.7 455.6 192.3	\$6,480 \$6,480 \$10,200,000 \$609,000 \$197,300 \$197,300	\$4,700 \$4,700 \$3,290,000 \$536,000 \$62,000 \$62,000
WASIEPILI Wastepile Cover-30 mil HDPE Thin-Film Stripping WASTEPIL Wastepile Cover-30 mil HDPE Thin-Film Evaporator	Aqueous Sludge Two-Phase Aqueous/Organic Sludge Two-Phase Aqueous Two-Phase Aqueous/Organic Sludge Two-Phase Aqueous Sludge Aqueous Sludge	120,000 120,000 120,000 120,000 120,000 120,000 170,000 170,000	139.7 100.0 139.7 100.0 390.0 457.0	139.3 49.3 137.3 62.7 455.6 192.3 453.6	\$6,480 \$6,480 \$10,200,000 \$609,000 \$197,300 \$197,300 \$14,400,000	\$4,700 \$4,700 \$3,290,000 \$536,000 \$62,000 \$4,690,000

EMISSION Control	MODEL Waste type	ANNUAL THROUGHPUT (Mg/yr)	C: UNCONTROLLED EMISSIONS (Mg/yr)	d ENISSION REDUCTION (Mg/yr)	TOTAL CAPITAL INVESTMENT	TOTAL ANNUAL COSTS			
SURFACE IMPOUNDMENT STORAGE									
QUIESCENT STORAGE IMPOUNDMENT (SO4A) - 71,300 gal impoundment									
ASP+FBCA	Aqueous Sludge	99,000	278	264	\$181,000	\$84,000			
	Dilute Aqueous-1	99,000	114	108	\$177,000	\$78,000			
	Two-Phase Aqueous/Organic	99,000	191	181	\$177,000	\$78, 000			
HEMBRANE	Aqueous Sludge	99,000	278	236	\$15,000	\$ 8, 000			
	Dilute Aqueous-1	99,000	114	97	\$15,000	\$8,000			
	Two-Phase Aqueous/Organic	99,000	191	162	\$15,000	\$8,000			
Thin-Film Evaporator	Aqueous Sludge	99,000	278	276.0	\$8, 390,000	\$84,000			
			*****	************		******			
Steam Stripping	Dilute Aqueous-1	99,000	114	113.7	\$503,000	\$84,000			
	; Two-Phase Aqueous/Organic	99,000	191	159.5	\$503,000	\$84,000			
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See notes at end of table.

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b Emission Control	MODEL WASTE TYPE	ANNUAL THROUGHPUT (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TOTAL CAPITAL INVESTMENT	TOTAL Annual Costs			
SURFACE IMPOUNDMENT STORAGE									
QUIESCENT STORAGE IMPOUNDMENT (S04B) - 71,300 gal impoundment									
ASP+FBCA	Aqueous Sludge	9,800	140	133	\$180,000	\$78, 000			
	Dilute Aqueous-i	9,800	32	30	\$179,000	\$74,0 00			
	, Two-Phase Aqueous/Organic	9,800	36	34	\$179,000	\$74,000			
MEMBRANE	Aqueous Sludge	9,800	140	117	\$15,000	\$8,000			
	Dilute Aqueous-1	9,800	32	27	\$15,000	\$8, 000			
	: Two-Phase Aqueous/Organic	9,800	36	31	\$15,000	\$8,000			
Thin-Film Evaporator	: Aqueous Sludge	9,800	140	139.8	\$830,000	\$276,000			
Steam Stripping	Dilute Aqueous-1	9,800	32	31.97	\$50,000	\$46,000			
	; Two-Phase Aqueous/Organic	9,800	36	32.9	\$50,000	\$46,000			
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See notes at end of table.

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EMISSION CONTROL	MODEL Waste type	ANNUAL Throughput (Mg/yr)	UNCONTROLLED EMISSIONS (Mg/yr)	d ENISSION REDUCTION ((Mg/yr)	TOTAL Capital Investment	TOTAL Annual Costs				
SURFACE IMPOUNDMENT STORAGE										
- QUIESCEN	T STORAGE IMPOUNI)MENT (S04C) -	713,000 gal imp	ooundment						
ASP+FBCA	Aqueous Sludge	49,000	686	652	\$311,000	\$42,000				
	Dilute Aqueous-1	49,000	159	151	\$249,000	\$42,000				
	: Two-Phase Aqueous/Organic	49,000	183	174	\$249,000	\$42,000				
MEMBRANE	Aqueous Sludge	49,000	686	583	\$57,000	\$16,200				
	Dilute Aqueous-1	49,000	159	135	\$57,000	\$16,200				
	: Two-Phase Aqueous/Organic	49,000	183	156	\$57,000	\$16,200				
hin-Film vaporator	Aqueous Sludge	49,000	686	685.0	\$4,150,000	\$1,3 8 2,000				
	,									
Steam tripping	Dilute Aqueous-1	49,000	159	158.8	\$249,000	\$226,000				
	: Two-Phase Aqueous/Organic	49,000	183	167.3	\$249,000	\$226,000				

See notes at end of table.

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TADLE CTO. SUPPLART OF ISDE PODEL UNIT ANALISIS RESU	TABLE	-6. SUMMARY	OF TSDF MODE	L UNIT ANALYSIS	RESULT
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b Emission Control	NODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d: ENISSION REDUCTION ; (Mg/yr) ;	TOTAL CAPITAL INVESTMENT	TOTAL Annual Costs				
SURFACE IMPOUNDMENT STORAGE										
BUIESCEN	T STORAGE IMPOUN	MENT (SO4D)	- 713,000 gal imp	oundment						
ASP+FBCA	Aqueous Sludge	25,000	442	420	\$310,000	\$127,000				
	Dilute Aqueous-1	25,000	157	147	\$310,000	\$114,000				
	Two-Phase Aqueous/Organic	25,000	93	88 ;	\$310,000	\$114,000				
MEMBRANE	Aqueous Sludge	25,000	442	376	\$57,000	\$17,000				
	Dilute Aqueous-1	25,000	157	133	\$57,000	\$17,0 00				
	Two-Phase Aqueous/Organic	25,000	93	79	\$57,000	\$17,000				
Thin-Film Evaporator	Aqueous Sludge	25,000	442	441.5	\$2,120,000	\$706,000				
				· · · · · · · · · · · · · · · · · · ·						
Steam Stripping	Dilute Aqueous-1	25,000	157	156.9	\$127,000	\$115,000				
	Two-Phase Aqueous/Organic	25,000	93	85.0	\$127,000	\$115,000				

					322222222222222	191292282332			
b Emission Control	MODEL Waste type	ANNUAL Throughput (Mg/yr)	UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TOTAL CAPITAL INVESTMENT	TOTAL Annual Costs			
SURFACE IMPOUNDMENT STORAGE									
QUIESCEN	T STORAGE IMPOUN)MENT (S04E) -	- 8,720,000 gal	iapoundment -					
ASP+FBCA	Aqueous Sludge	120,000	2,200	2,090	\$1,160,000	\$488, 000			
	Dilute Aqueous-1	120,000	446	424	\$804,000	\$284,000			
	; Two-Phase Aqueous/Organic	120,000	464	441	\$804,000	\$284,000			
MEMBRANE	Aqueous Sludge	120,000	2,200	1,870	\$300,000	\$65,000			
	Dilute Aqueous-1	120,000	446	379	\$300,000	\$65,000			
	: Two-Phase Aqueous/Organic	120,000	464	394	\$300,000	\$65,000			
*									
Thin-Film Evaporator	Aqueous Sludge	120,000	2,200	2197.5	\$10,170,000	\$3,413,000			
Steam Stripping	Dilute Aqueous-1	120,000	446	445.6	\$609,000	\$557,000			
	i Two-Phase Aqueous/Organic	120,000	464	425.3	\$60 9,000	\$557,000			
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TABLE C-6. SUMMARY OF TSDF MODEL UNIT ANALYSIS RESULT^a

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(continued)

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b Emission Control	MODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TDTAL CAPITAL Investment	TOTAL Annual Costs			
SURFACE IMPOUNDMENT STORAGE									
QUIESCENT STORAGE IMPOUNDMENT (S04F) - 8,720,000 gal impoundment									
ASP+FBCA	Aqueous Sludge	67,000	1,420	1,349	\$1,170,000	\$450,000			
	Dilute Aqueous-1	67,000	253	240	\$806,000	\$276,000			
	Two-Phase Aqueous/Organic	67,000	262	249	\$806,000	\$276,000			
MEMBRANE	Aqueous Sludge	67,000	1,420	1,207	\$300,000	\$65,000			
-	; Dilute Aqueous-1	67,000	253	215	\$300,000	\$65,000			
	i Two-Phase Aqueous/Organic	67,000	262	223	\$300,000	\$65,000			
Thin-Film Evaporator	l Aqueous Sludge	67,000	1,420	1418.6	\$5,680,000	\$1,890,000			
Steam Stripping	Dilute Aqueous-1	67,000	253	252.8	\$340,000	\$308,000			
	i Two-Phase Aqueous/Organic	67,000	262	240.6	\$340,000	\$30 8, 000			
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TABLE C-6. SUMMARY OF TSDF MODEL UNIT ANALYSIS RESULT^a

b Emission Control	NODEL Waste type	ANNUAL THROUGHPUT (Mg/yr)	C: UNCONTROLLED EMISSIONS (Mg/yr)	d: EMISSION : REDUCTION ; (Mg/yr) ;	TOTAL CAPITAL INVESTMENT	TOTAL Annual Costs				
TANK TREATMENT										
QUIESCEN	T UNCOVERED TREATHE	ENT TANK (TO1A) - 8,000 gal t	ank						
Fixed Roof	Aq Sludge	11,000	16	15.9	\$9,500	\$1,880				
	Dilute Aq	11,000	8.6	6.8	\$9,500	\$1,880				
	Org Liquid	11,000	467	466.5	\$9,500	\$1,880				
	Org Sludge/Slurry	11,000	523	522.4	\$9,500	\$1,880				
	Two-Phase Aq/Org	11,000	14	13.2	\$9,500	\$1,880				
Internal	Aq Sludge	11,000	16	15.98	\$16,450	\$4,090				
Roof	Dilute Aq	11,000	8.6	8.12	\$16,450	\$4,090				
roof)	Org Liquid	11,000	467	466.91	\$16,450	\$4,090				
	Org Sludge/Slurry	11,000	523	522.90	\$16,450	\$4,090				
	Two-Phase Aq/Org	11,000	14	13.83	\$16,450	\$4,090				
Vent to	Aq Sludge	11,000	16	15.995	\$11,080	\$2,210				
Control	Dilute Aq	11,000	8.6	8.51	\$11,080	\$2,210				
(+ fixed	Org Liquid	11,000	467	466.98	\$11,080	\$2,210				
r00t)	Org Sludge/Slurry	11,000	523	522.97	\$11,080	\$2,210				
	Two-Phase Aq/Org	11,000	14	13.96	\$11,080	\$2,210				
Vent to	Aq Sludge	11,000	16	15.995	\$10,550	\$7,300				
Canister Canister	Dilute Aq	11,000	8.6	8.5	\$10,550	\$7,300				
roof)	Org Liquid	11,000	467	466.98	\$10,550	\$7,300				
	Org Sludge/Slurry	11,000	523	522.97	\$10,550	\$7,300				
	Two-Phase Aq/Org	11,000	14	13.96	\$10,550	\$7,300				
Thin-File Evaporator	Aqueous Sludge	11,000	16	15.4	\$930,000	\$313,000				
Stea s Stripping	Dilute Aqueous-1	11,000	8.6	8.5	\$56,000	\$51,000				
	Two-Phase Aqueous/Organic	11,000	14	5.0	\$56,000	\$51,000				
Batch Distillation	l Organic Liquid	11,000	467	460.3	\$206,000	(\$223,000)				
Rotary Kiln Incinerator	: Organic Sludge/Slurry	11,000	523	520.2	\$5,300,000	\$1,650,000				
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See notes at end of table.

EMISSION CONTROL	MODEL Waste Type	ANNUAL THROUGHPUT (Mg/yr)	UNCONTROLLED EMISSIONS ((Mg/yr)	EMISSION : REDUCTION : (Mg/yr) :	TOTAL CAPITAL INVESTMENT	TDTAL Annual Costs
		TAN	IK TREATMENT			
QUIESCEN	T UNCOVERED TREATME	NT TANK (TOII	3) - 20,000 gal	tank		
Fixed Roof	Aq Sludge	28,000	34	33.8	\$14,800	\$3,050
	Dilute Aq	28,000	19	14.4	\$14,800	\$3,050
	Org Liquid	28,000	954	952.8	\$14,800	\$3,050
	Org Sludge/Slurry	28,000	1,026	1,024.6	\$14,800	\$3,050
	Two-Phase Aq/Org	28,000	31	29.1	\$14,800	\$3,050
Internal	Aq Sludge	28,000	34	33.96	\$24,420	\$6,100
Roof	Dilute Aq	28,000	19	17.80	\$24,420	\$6,100
(+ f1xe0 roof)	Org Liquid	28,000	954	953.79	\$24,420	\$6,100
	Org Sludge/Slurry	28,000	1,026	1025.75	\$24,420	\$6,100
	Two-Phase Aq/Org	28,000	31	30.57	\$24,420	\$6,100
Vent to Existing Control Device (+ fixed	Aq Sludge	28,000	34	33.99	\$16,380	\$3,350
	Dilute Aq	28,000	19	18.8	\$16,380	\$3,350
	Org Liquid	28,000	· 954	953.9	\$16,380	\$3,350
root)	Org Sludge/Slurry	28,000	1,026	1025.9	\$16,380	\$3,350
	Two-Phase Aq/Org	28,000	31	30.9	\$16,380	\$3,350
Vent to	Aq Sludge	28,000	34	33.99	\$15,850	\$15,790
Canister	Dilute Aq	28,000	19	18.8	\$15,850	\$188,920
roof)	Org Liquid	28,000	954	953.9	\$15,850	\$53,460
	Org Sludge/Slurry	28,000	1,026	1025.9	\$15,850	\$20,220
	Two-Phase Aq/Org	28,000	31	30.9	\$15,850	\$82,830
Thin-Film Evaporator	l Aqueous Sludge	28,000	34	33.4	\$2,370,000	\$790,000
Steam Stripping	Dilute Aqueous-1	28,000	19	18.9	\$142,000	\$129,000
	Two-Phase Aqueous/Organic	28,000	31	22.0	\$142,000	\$129,000
Batch Distillation	l Organic Liquid	28,000	954	947.3	\$524,000	(\$564,000)
Rotary Kiln Incinerator	l Organic Sludge/Slurry	28,000	1,026	1023.2	\$13,400,000	\$4,180,000

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b Emission Control	MODEL WASTE TYPE	ANNUAL Throughput (Hg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d: ENISSION : REDUCTION : (Mg/yr) :	TOTAL CAPITAL INVESTMENT	TOTAL Annual Costs
889\$%88 \$ \$ \$ \$		TAN	IK TREATMENT			
QUIESCEN	T UNCOVERED TREATME	ENT TANK (TOI)	c) - 210,000 gal	tank		
Fixed Roof	Aq Sludge	290,000	83	80.6	\$26,040	\$5,810
	Dilute Aq	290,000	53	5.8	\$26,040	\$5,810
	Org Liquid	290,000	4,770	4,759	\$26,040	\$5,810
	Org Sludge/Slurry	290,000	5,320	5,306	\$26,040	\$5,810
	Two-Phase Aq/Org	290,000	98	78.1	\$26,040	\$5,810
Internal	Aq Sludge	290,000	83	68.06	\$40,560	\$11,620
Floating Roof	Dilute Aq	290,000	53	60.16	\$40,560	\$11,620
(+ fixed roof)	Org Liquid	290,000	4,770	3912.44	\$40,560	\$11,620
	Org Sludge/Slurry	290,000	5,320	5219.01	\$40,560	\$11,620
	Two-Phase Aq/Org	290,000	98	1243.69	\$40,560	\$11,620
Vent to Existing Control	i Aq Sludge	290,000	83	82.88	\$42,460	\$8,720
	Dilute Aq	290,000	53	50.64	\$42,460	\$8,720
Device (+ fixed	Org Liquid	290,000	4,770	4769.45	\$42,460	\$8,720
roof)	Org Sludge/Slurry	290,000	5,320	5319.28	\$42,460	\$8,720
	Two-Phase Aq/Org	290,000	98	97.01	\$42,460	\$8,720
Vent to	Aq Sludge	290,000	B3	82.68	\$100,220	\$58,120
Fixed Bed Carbon	Dilute Aq	290,000	53	50.64	\$100,220	\$58,120
Adsorber (+ fixed	Org Liquid	290,000	4,770	4769.45	\$100,220	\$58,120
root)	Org Sludge/Slurry	290,000	5,320	5319.28	\$100,220	\$58,120
	: Two-Phase Aq/Org	290,000	98	97.01	\$100,220	\$58,120
Thin-Film Evaporator	Aqueous Sludge	290,000	34	28.1	\$24,630,000	\$8,196,000
Stean Stripping	Dilute Aqueous-1	290,000	19	18.1	\$1,473,000	\$1,336,000
	Two-Phase Aqueous/Organic	290,000	31	30.9	\$1,476,000	\$1,336,000
Batch Distillation	l Organic Liquid	290,000	954	884.2	\$5,432,000	¦(\$5,850,000
Rotary Kiln Incinerator	l Organic Sludge/Slurry	290,000	1,026	996.9	\$139,000,000	\$43,400,000

See notes at end of table.

EMISSION CONTROL	MODEL Waste Type	ANNUAL THROUGHPUT (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	di EMISSION REDUCTION (Mg/yr)	TOTAL - Capital Investment	TOTAL Annuac Costs			
TANK TREATMENT									
COVERED	QUIESCENT TREATMENT	TANK (TO1D)	- 8,000 gal tar	1k					
Internal	Aq Sludge	11,000	0.0953	0.0B	\$8,400	\$2,660			
Roof	Dilute Aq	11,000	1.83	1.35	\$8,400	\$2,660			
	Org Liquid	11,000	0.473	0.39	\$8,400	\$2,660			
	Org Sludge/Slurry	11,000	0.56	0.46	\$8,400	\$2,660			
	Two-Phase Aq/Org	11,000	0.769	0.60	\$8,400	\$2,660			
Yent to	Aq Sludge	11,000	0.0953	0.09	\$1,600	\$330			
Control	Dilute Aq	11,000	1.83	1.74	\$1,600	\$330			
DEAICE	Org Liquid	11,000	0.473	0.45	\$1,600	\$330			
	Org Sludge/Slurry	11,000	0.56	0.53	\$1,600	\$330			
	Two-Phase Aq/Org	11,000	0.769	0.73	\$1,600	\$330			
Vent to	Aq Sludge	11,000	0.0953	0.09	\$1,050	\$5,420			
Canister	Dilute Aq	11,000	1.83	1.74	\$1,050	\$74,500			
	Org Liquid	11,000	0.473	0.45	\$1,050	\$20,480			
	Org Sludge/Slurry	11,000	0.56	0.53	\$1,050	\$23,690			
	Two-Phase Aq/Org	11,000	0.769	0.73	\$4,900	\$32,210			
Thin-Film Evaporator	: Aqueous Sludge	11,000	0.0953	0.1	\$930,000	\$ 3 13,000			
Steam Stripping	i Dilute Aqueous-1	11,000	1.83	1.8	\$56,000	\$51,000			
	Two-Phase Aqueous/Organic	11,000	0.769	0.8	\$56,000	\$51,000			
Batch Distillation	l Organic Liquid	11,000	0.473	0.5	\$206,000	(\$223,000)			
Rotary Kiln Incinerator	l Organic Sludge/Slurry	11,000	0.56	0.6	\$5,300,000	\$1,650,000			

See notes at end of table.

EMISSION Control	HODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d: EMISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL Annual Costs			
TANK TREATMENT									
COVERED QUIESCENT JREATMENT TANK (TOIE) - 20,000 gal tank									
Internal	Aq Sludge	28,000	0.24	0.20	\$11,380	\$3,600			
Floating Roof	Dilute Aq	28,000	4.60	3.40	\$11,380	\$3,600			
	Org Liquid	28,000	1.19	0.98	\$11,380	\$3,600			
	Org Sludge/Slurry	28,000	1.40	1.15	\$11,380	\$3,600			
	Two-Phase Aq/Org	28,000	1.94	1.51	\$11,380	\$3,600			
Vent to	Aq Sludge	28,000	0.24	0.23	\$1,600	\$300			
Existing Control	Dilute Aq	28,000	4.60	4.37	\$1,600	\$300			
Device	Org Liquid	28,000	1.19	1.13	\$1,600	\$300			
	Org Sludge/Slurry	28,000	1.40	1.33	\$1,600	\$300			
	: Two-Phase Aq/Org	28 ,0 00	1.94	1.84	\$1,600	\$300			
Vent to	Aq Sludge	28,000	0.24	0.23	\$1,050	\$12,740			
Carbon Canister	Dilute Aq	28,000	4.60	4.37	\$1,050	\$185,870			
	Org Liquid	28,000	1.19	1.13	\$1,050	\$50,410			
	Org Sludge/Slurry	28,000	1.40	1.33	\$1,050	\$5,900			
	i Two-Phase Aq/Org Two-Phase	28,000	1.94	1.84	\$1,050	\$79,780			
Thin-Film Evaporator	: Aqueous : Sludge	28,000	0.24	0.2	\$2,370,000	\$790,000			
Steam Stripping	Dilute Aqueous-1	28,000	4.60	4.5	\$142,000	\$129,000			
	Two-Phase Aqueous/Organic	28,000	1.94	1.9	\$142,000	\$129,000			
Batch Distillation	l Organic Liquid	28,000	1.11	1.1	\$524,000	(\$564,000)			
Rotary Kiln Incinerator	: Organic : Sludge/Slurry	28,000	1.35	1.4	\$13,400,000	\$4,180,000			

See notes at end of table.

	TABLE	C-6.	SUMMARY	0F	TSDF	MODEL	UNIT	ANALYSIS	RESULT	a
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EMISSION CONTROL	MODEL Waste type	ANNUAL THROUGHPUT (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSIDN REDUCTION (Hg/yr)	TOTAL Capital Investment	i TDTAL ANNUAL COSTS					
	TANK TREATMENT										
COVERED	COVERED QUIESCENT TREATMENT TANK (TOIF) - 210,000 gal tank										
Internal	Aq Sludge	290,000	2.45	2.01	\$19,660	\$5,810					
Roof	Dilute Aq	290,000	47.23	34.95	\$19,660	\$5,810					
	Org Liquid	290,000	11.05	9.06	\$19,660	\$5,810					
	Org Sludge/Slurry	290,000	14.32	11.74	\$19,660	\$5,810					
	Two-Phase Aq/Org	290,000	19.89	15.52	\$19,660	\$5,810					
Vent to	Aq Sludge	290,000	2.45	2.32	\$1,600	\$300					
Control	Dilute Aq	290,000	47.23	44.87	\$1,600	\$300					
DEALCE	Org Liquid	290,000	11.05	10.49	\$1,600	\$300					
	Org Sludge/Slurry	290,000	14.32	13.60	\$1,600	\$300					
	Two-Phase Aq/Org	290,000	19.89	18.90	\$1,600	\$300					
Vent to	Aq`Sludge	290,000	2.45	2.32	\$74,180	\$52,310					
Carbon	Dilute Aq	290,000	47.23	44.87	\$74,180	\$52,310					
Razor ner	Drg Liquid	290,000	11.05	10.49	\$74,180	\$52,310					
	Org Sludge/Slurry	290,000	14.32	13.60	\$74,180	\$52,310					
	Two-Phase Aq/Org	290,000	19.89	18.90	\$74,180	\$52,310					
Thin-Fil a Evaporator	l Aqueous l Sludge l	290,000	2 .45	2,4	\$24,580,000	\$8,196, 000					
Steam Stripping	Dilute Aqueous-1	290,000	47.23	46.3	\$1,473,000	\$1,336,000					
	Two-Phase Aqueous/Organic	290,000	19.89	19.9	\$1,476,000	\$1,336,000					
Batch Distillation	l Organic Liquid	290,000	11.05	11.0	\$5,432,000	(\$5,850,000)					
Rotary Kiln Incinerator	l Organic Sludge/Slurry	290,000	14.32	14.3	\$139,000,000	\$ 4 3,400,000					

b Emission Control	MODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	CI UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TOTAL CAPITAL INVESTMENT	TOTAL ANNUAL COSTS					
TANK TREATMENT											
UNCOVERE	UNCOVERED AERATED/AGITATED TREATMENT TANK (TOIS) - 28,500 gal tank										
ASP+FBCA	Aqueous Sludge	240,000	970	827	\$124,000	\$66,600					
	Dilute Aqueous-1	240,000	130	124	\$125,000	\$94,800					
Thin-Film Evaporator	Aqueous Sludge	240,000	870	865.1	\$20,300,000	\$6,760,000					
Steaø Stripping	Dilute Aqueous-1	240,000	130	129.2	\$1,220,000	\$1,100,000					
UNCOVEREI	UNCOVERED AERATED/AGITATED TREATMENT TANK (TO1H) - 423,000 gal tank										
ASP+FBCA	Aqueous Sludge	2,800,000	10,600	10,070	\$732,000	\$607,000					
	Dilute Aqueous-1	2,800,000	4,500	4,370	\$732,00 0	\$607,000					
Thin-Film Evaporator	Aqueous Sludge	2,800,000	10,600	10543.7	\$237,300,000	\$77,840,000					
Steam ; Stripping ;	Dilute Aqueous-1	2,800,000	4,600	4591.2	\$14,220,000	\$12,690,000					
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See notes at end of table.

EMISSION CONTROL	MODEL Waste Type	ANNUAL Throughput (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d : EMISSION REDUCTION ; (Mg/yr) ;	TOTAL CAPITAL INVESTMENT	TOTAL ANNUAL COSTS
		SUR	FACE IMPOUNDMEN	IT TREATMENT		
QUIESCE	NT TREATMENT IMPOL	INDMENT (TO2A)	71,300 gal i	.mpoundment		
ASP+FBCA	Aqueous Sludge	200,000	301	286	\$181,200	\$85,300
	Dilute Aqueous-1	200,000	135	129	\$179,800	\$83,300
	i Two-Phase Aqueous/Organic	200,000	265	252	\$179,800	\$83,300
MEMBRANE	Aqueous Sludge	200,000	301	256	\$14,760	\$8,000
	Dilute Aqueous-1	200,000	135	115	\$14,760	\$8,000
	Two-Phase Aqueous/Organic	200,000	265	225	\$14,760	\$8 ,000
Thin-Film Evaporator	Aqueous Sludge	200,000	301	297.0	\$16,950,000	\$5,590,000
Steam Stripping	Dilute Aqueous-1	200,000	135	134.4	\$1,016,000	\$910,000
	Two-Phase Aqueous/Organic	200,000	265	201.6	\$1,016,000	\$910,000

EMISSION Control	MODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSIDN REDUCTION (Mg/yr)	TOTAL CAPITAL INVESTMENT	TOTAL Annual Costs					
SURFACE IMPOUNDMENT TREATMENT											
QUIESCEN	QUIESCENT TREATMENT IMPOUNDMENT (TO2B) - 71,300 gal impoundment										
ASP+FBCA	Aqueous Sludge	20,000	191	181	\$176,900	\$79,200					
	Dilute Aqueous-1	20,000	53	50	\$171,800	\$72,600					
	Two-Phase Aqueous/Organic	20,000	65	62	\$171,800	\$72,600					
MEMBRANE	Aqueous Sludge	20,000	191	162	\$14,760	\$8,000					
	Dilute Aqueous-1	20,000	53	45	\$14,760	\$8,000					
	Two-Phase Aqueous/Organic	20,000	65	55	\$14,760	\$8 ,000					
Thin-Fil a Evaporator	Aqueous Sludge	20,000	191	190.5	\$1,700,000	\$560,000					

Steam Stripping	Dilute Aqueous-1	20,000	53	52.9	\$102,000	\$91,000					
	Two-Phase Aqueous/Organic	20,000	65	58.6	\$102,000	\$91,000					
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See notes at end of table.

b Emission Control	MODEL Waste type	ANNUAL Throughput (Mg/yr)	UNCONTROLLED EMISSIONS (Mg/yr)	d ENISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL ANNUAL COSTS					
SURFACE IMPOUNDMENT TREATMENT											
QUIESCENT TREATMENT IMPOUNDMENT (TO2C) - 713,000 gal impoundment											
ASP+FBCA	Aqueous Sludge	990,000	1,400	1,330	\$280,600	\$147,900					
	Dilute Aqueous-1	990,000	700	665	\$277,500	\$147,900					
	Two-Phase Aqueous/Organic	990,000	1,320	1,254	\$277,500	\$147,900					
MEMBRANE	Aqueous	790,000	191	162	\$57,000	\$19,700					
	Dilute Aqueous-1	990,000	53	45	\$57,000	\$19,700					
	l Two-Phase Aqueous/Organic	990,000	65	55	\$57,000	\$19,700					
Thin-Fil s Evaporator	Aqueous Sludge	990,000	1,400	1,379.9	\$33,910,000	\$27,8 10,000					
Steam Stripping	Dilute Aqueous-1	990,000	700	696.8	\$5,028,000	\$4,534,000					
	: Two-Phase Aqueous/Organic	990,000	1,320	1,004.5	\$5,028,000	\$4,534,000					

See notes at end of table.

TABLE	C-6.	SUMMARY	0F	TSDF	MODEL	UNIT	ANALYSIS	RESULT

EMISSION Control	MODEL WASTE TYPE	ANNUAL THROUGHPUT (Mg/yr)	UNCONTROLLED Emissions (Mg/yr)	e ENISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL ANNUAL COSTS						
QUIESCEN	QUIESCENT TREATMENT IMPOUNDMENT (TO2D) - 713,000 gal impoundment											
ASP+FBCA	Aqueous Sludge	99,000	946	899	\$262,800	\$128,200						
	Dilute Aqueous-1	99,000	269	256	\$237,500	\$97,600						
	Two-Phase Aqueous/Organic	99,000	326	310	\$237,500	\$97,600						
MEMBRANE	Aqueous Sludge	99 ,000	191	162	\$57,000	\$15,800						
	Dilute Aqueous-I	99,000	53	45	\$57,000	\$15,800						
	Two-Phase Aqueous/Drganic	99,000	65	55	\$57,000	\$15,800						
			* = = = = = = = = = = = = = = = = = = =									
Thin-Filæ Evaporator	Aqueous Sludge	99,000	9 46 ;	944.0	\$8,390,000	\$2,780,000						
Steam Stripping	Dílute Aqueous-1	99,000	269	268.7	\$503 ,00 0	\$454,000						
	Two-Phase Aqueous/Organic!	99,000	326	294.5	\$503,000	\$454,000						
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TABLE	C-6.	SUMMARY	0F	TSDF	MODEL	UNIT	ANALYSIS	RESULTa

EMISSION CONTROL	MODEL WASTE TYPE	ANNUAL THROUGHPUT (Mg/yr)	C: UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL Annual Costs
		SUF	RFACE IMPOUNDMENT	TREATMENT		
QUIESCEN	T TREATMENT IMPO	INDMENT (TO2E)) 8,720,000 gal	impoundment		
ASP+FBCA	Aqueous Sludge	608,000	5,530	5,254	\$636,600	\$395,200
	Dilute Aqueous-l	608,000	1,710	1,625	\$500,000	\$224,900
	Two-Phase Aqueous/Organic	608,000	2,040	1,938	\$500,000	\$224,900
MEMBRANE	Aqueous Sludge	608, 000	191	162	\$300,070	\$10,800
	Dilute Aqueous-1	608,000	53	45	\$300,070	\$10,800
	¦ Two-Phase }Aqueous/Organic	608, 000	65	55	\$300,070	\$10,300
	 ;		i			
Thin-Film Evaporator	l Aqueous Sludge	608,000	5,530	5,517.6	\$51,530,000	¦\$17,140,000 ¦
Steam Stripping	Dilute Aqueous-1	608,000	1,710	1,708.1	\$3,088,000	\$2,795,000
	Two-Phase Aqueous/Organic	60 8,0 00	2,040	1,845.5	\$3,088,000	\$2,796,000

EMISSION CONTROL	MODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	C' UNCONTROLLED EMISSIONS (Mg/yr)	d : EMISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL Annual Costs
		SUR	FACE IMPOUNDMEN	T TREATMENT		
QUIESCEN	T TREATMENT INPOU	NDMENT (TO2F)	8,720,000 ga	l impoundment		
ASP+FBCA	Aqueous Sludge	302,400	4,030	3,829	\$577,900	\$321,000
	Dilute Aqueous-1	302,400	990	941	\$461,500	\$169,300
	Two-Phase	302,400	1,120	1,064	\$461,500	\$169,300
MEMBRANE	Aqueous Sludge	302,400	191	162	\$300,070	\$6 6,500
	Dilute Aqueous-1	302,400	53	45	\$300,070	\$66,500
	Two-Phase Aqueous/Organic:	302,400	65	55	\$300,070	\$66,500
Thin-Fila Evaporator	l Aqueous ! Sludge :	302,400	4,030	4,023.8	\$25,630,000	\$8,5 30,000
	1				1	
Steam Stripping	Dilute Aqueous-1	302,400	990	989.0	\$1,536,000	\$1,391,000
	Two-Phase Aqueous/Organic	302,400	1,120	1,023.2	\$1,536,000	\$1,391,000
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TABLE C-6. SUMMARY OF TSDF MODEL UNIT ANALYSIS RESULT^a

ENISSION CONTROL	MODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	C; UNCONTROLLED Emissions (Mg/yr)	d ENISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL Annual Costs						
	SURFACE IMPOUNDMENT TREATMENT											
AERATED/	AERATED/AGITATED TREATMENT INPOUNDMENT (T026) - 71,300 gal impoundment											
ASP+FBCA	Aqueous Sludge	200,000	683	649	\$196,200	\$103,000						
	Dilute Aqueous-l	200,000	760	722	\$199,200	\$107,000						
	l Two-Phase Aqueous/Organic	200,000	763	725	\$199,200	\$107,0 00						
Thin-Fila Evaporator	 Aqueous Sludge	200,000	683	679.0	\$16,950,000	\$5,590, 000						
Steam Stripping	Dilute Aqueous-1	200,000	760	759.4	\$1,016,000	\$910,000						
	Two-Phase Aqueous/Organic	200,000	763	699.6	\$1,015,000	\$910,000						
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AERATED/	AGITATED TREATMEN	NT IMPOUNDMENT	r (TO2H) 71,30	0 gal impound	ment							
ASP+FBCA	Aqueous Sludge	20,000	302	287	\$181,300	\$9,000						
	Dilute Aqueous-1	20,000	78	74	\$179,000	\$8, 000						
	Two-Phase Aqueous/Organic	20,000	77	73	\$179,000	\$8,000						
Thin-Film Evaporator	Aqueous Sludge	20,000	302	301.6	\$1,700,000	\$560,000						
Steam	Dilute	20,000	78	77.9	\$102,000	\$91,000						
stri pp ing	i Aqueous-1 Two-Phase Aqueous/Organic	20,000	77	70.6	\$102,000	\$91,000						
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See notes at end of table.

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B EMISSION CONTROL	MODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d: EMISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL ANNUAL COSTS		
SURFACE IMPOUNDMENT TREATMENT								
AERATED/AGITATED TREATMENT IMPOUNDMENT (TO2I) - 713,000 gal impoundment								
ASP+FB CA	Aqueous Sludge	990,000	6,530	6,204	\$481, 0 00	\$404,000		
	i Dilute Aqueous-1	990,000	3,800	3,610	\$376,000	\$266,000		
	Two-Phase Aqueous/Organic	990,000	3,860	3,667	\$376,000	\$266,000		
Thin-Fil a Evaporator	l Aqueous Sludge	990,000	6,530	6,510	\$83,910,000	\$27,810,000		
Steam Stripping	: Dilute Aqueous-1	990,000	3,800	3,797	\$5,028,000	\$4,534,000		
	Two-Phase Aqueous/Organic	770,000	3,860	3,545	\$5,028,000	\$4,534,000		
ACDATED ADVITATED TREATMENT (MODININGNET (TO21) = 713 000 col inconstants								
ASP+FBCA	Aqueous Sludge	99,000	1,920	1,824	\$305,000	\$177,000		
	Dilute Aqueous-1	99,000	390	371	\$298,000	\$122,000		
	Two-Phase Aqueous/Organic	99,000	380	361	\$298,000	\$122,000		
Thin-Film Evaporator	i Aqueous Sludge	99,000	1,920	1,918	\$8,390,000	\$2,790,000		
Steam Stripping	Dilute Aqueous-1	99,000	390	389.7	\$503,000	\$455,000		
	¦ Two-Phase ¦Aqueous/Organic	99,000	280	348	\$503,000	\$455,000		
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See notes at end of table.

CONTROL	MODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TOTAL CAPITAL INVESTMENT	i I TOTAL I ANNUAL I COSTS
		SUR	RFACE IMPOUNDMEN	IT TREATMENT -		***********
AERATED,	AGITATED TREATMEN	IT IMPOUNDMENT	r (TO2K) - 8,72(),000 gal impo	undaent	
ASP+FBCA	Aqueous Sludge	608,000	12,160	11,552	\$777,000	\$693,000
	Dilute Aqueous-i	608,000	2,300	2,185	\$512,000	\$237,000
	Two-Phase Aqueous/Organic	608,000	2,400	2,280	\$512,000	\$237,000
Thin-Film Evaporator	Aqueous Sludge	60B,000	12,160	12,148	\$51,530,000	\$17,140,000
Steam Stripping	Dilute Aqueous-1	608,000	2,300	2,298	\$3,0 88 ,000	\$2,796,000
	Two-Phase Aqueous/Organic	608,000	2,400	2,205	\$3,088,000	\$2,796,000
AERATED.	/AGITATED TREATMEN	IT IMPOUNDMENT	(TO2L) - 8,720),000 gal impo	undment	
AERATED. ASP+FBCA	/AGITATED TREATMEN Aqueous Sludge	NT IMPDUNDMENT 302,000	(TO2L) - 8,720 6,520),000 gal impc 6,194 f	undment \$675,000	\$ 445. 000
AERATED. ASP+FBCA	/AGITATED TREATMEN Aqueous Sludge Dilute Aqueous-1	IT IMPDUNDMEN 302,000 302,000	(TO2L) - 8,720 6,520 810	0,000 gal impc 6,194 770	undment \$675,000 \$460,000	\$445,000 \$169,000
AERATED. ASP+FBCA	/AGITATED TREATME Aqueous Sludge Dilute Aqueous-1 Two-Phase Aqueous/Drganic	IT IMPDUNDMEN 302,000 302,000 302,000	(TO2L) - 8,720 6,520 810 1,200	0,000 gal impc 6,194 770 1,140	undment \$675,000 \$460,000 \$460,000	\$445,000 \$169,000 \$159,000
AERATED ASP+FBCA Thin-Fila Evaporator	/AGITATED TREATME) Aqueous Sludge Dilute Aqueous-1 Two-Phase Aqueous/Drganic	IT IMPOUNDMEN 302,000 302,000 302,000 302,000	(TO2L) - 8,720 6,520 810 1,200 6,520	6,000 gal impc 6,194 770 1,140 6,514	undment \$675,000 \$460,000 \$460,000 \$460,000	\$445,000 \$169,000 \$159,000 \$8,520,000
AERATED ASP+FBCA Thin-Fila Evaporator Stean Stripping	AGITATED TREATMEN Aqueous Sludge Dilute Aqueous-1 Two-Phase Aqueous/Drganic Sludge Dilute Aqueous-1	IT IMPOUNDMEN 302,000 302,000 302,000 302,000 302,000	(TO2L) - 8,720 6,520 810 1,200 6,520 810	9,000 gal impo 6,194 770 1,140 6,514 809	<pre>bundment \$675,000 \$460,000 \$460,000 \$25,600,000 \$1,534,000</pre>	\$445,000 \$169,000 \$159,000 \$8,520,000 \$1,389,000

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EMISSION Control	MODEL NASTE TYPE	ANNUAL Throughput (Mg/yr)	CI UNCONTROLLED Emissions (Mg/yr)	d EMISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL Annual Costs		
WASTE FIXATION								
WASTE FIXATION (Fixation Fit A)								
Mixer Baghouse, & FBCA	Aqueous Sludge	17,000	51.0	4B.0	\$464,000	\$22 8, 000		
	Two-Phase Aqueous/Organic	17,000	51.0	50.0	\$464,000	\$228,000		
Thin-Film Evaporator	Aqueous Sludge	17,000	51.0	50.7	\$1,400,000	\$470,000		
Steam Stripping	¦ Two-Phase ¦Aqueous/Organic	17,000	51.0	45.6	\$86,000	\$78,000		
WASTE FIYATION (Fivation Dit B)								
Mixer Baghouse, & FBCA	Aqueous Sludge	117,000	351.0	330	\$572,000	\$213,000		
	Two-Phase Aqueous/Organic	117.000	351.0	300	\$572,000	\$213,000		
Thin-Film Evaporator	l Aqueous Sludge	117,000	351.0	348.6	\$9,900,000	\$3,300,000		
Steam Stripping	i Two-Phase Aqueous/Organic	117,000	351.0	313.6	\$594,000	\$53B,000		
WASTE FIXATION (Fixation Pit C)								
Mixer Baghouse,	Aqueous Sludge	167,000	501.0	480	\$616,000	\$277,000		
€ FBCA	Two-Phase Aqueous/Drganic	167,000	501.0	500	\$616,000	\$277 ,00 0		
Thin-Film Evaporator	Aqueous Sludge	167,000	501.0	497.6	\$14,200,000	\$4,720,000		
Steam Stripping	Two-Phase Aqueous/Organic	167,000	501.0	447.6	\$948,000	\$767,000		

See notes at end of table.
b Emission Control	MODEL WASTE TYPE	ANNUAL THROUGHPUT (Mg/yr)	C UNCONTROLLED Emissions (Mg/yr)	d ENISSION REDUCTION (Hg/yr)	TOTAL Capital Investment	TOTAL Annual Costs
		LA	NDFILL DISPOSAL			
ACTIVE L	ANDFILL (D80D) -	1 acre				
Daily Earth Cover	l Aqueous l Sludge l	16,650	100.6	11.1	\$0	\$44,800
	l Two-Phase l Aqueous/Organic:	16,650	86.1	9.5	\$0	\$44,800
Thin-File Evaporator	i Aqueous i Sludge i	16,650	100.6	100.29	\$1,400,000	\$460,000
Steam Stripping	: Two-Phase : Aqueous/Organic:	16,650	86.1	80.8	\$85,000	\$76,000
ACTIVE	LANDFILL (D80E) -	3.5 acres			;22222222;23;2;	
Daily Earth Cover	l Aqueous Sludge	116,500	358.1	39.4	\$0	\$313,400
	l Two-Phase Aqueous/Organic	116,500	299	32.9	\$0	\$313,400
Thin-File Evaporator	: Aqueous : Sludge	116,500	358.1	355.72	\$9,900,000	\$3,290,000
Steam Stripping	¦ Two-Phase ¦Aqueous/Organic	116,500	299	261.7	\$592,000	\$536,000
ACTIVE	LANDFILL (D80F) -	5 acres		==========		
Daily Earth Cover	l Aqueous Sludge	166,500	510.9	56.2	\$0	\$447,900
	l Two-Phase Aqueous/Organic	166,500	427	47	\$0	\$447,900
Thin-File Evaporator	i Aqueous Sludge	166,500	510.9	507.51	\$14,100,000	\$4,690,000
Steam Stripping	¦ Two-Phase ¦Aquebus/Organic	166,500	427	373.7	\$846,000	\$766,000
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TABLE C-6. SUMMARY OF TSDF MODEL UNIT ANALYSIS RESULT^a

See notes at end of table.

TABLE C-6. SUMMARY OF TSDF MODEL UNIT ANALYSIS RESULT^a

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EMISSION Control	MODEL WASTE TYPE	ANNUAL Throughput (Mg/yr)	C UNCONTROLLED EMISSIONS (Mg/yr)	d: EMISSION : REDUCTION : (Mg/yr) :	TOTAL CAPITAL INVESTMENT	TOTAL Annual Costs
		LAN	IDFILL DISPOSAL			
CLOSING	LANDFILL (D80G) -	1 acre				
C.Landfill 30 mil-HDPE	Aqueous Sludge	16,650	0.020	0.019	\$17,260	\$2,000
	Two-Phase Aqueous/Organic	16,650	0.6	0.29	\$17,260	\$2,000
C.Landfill 100 mil-HDPE	Aqueous Sludge	16,650	0.020	0.019	\$44,490	\$6,000
	l Two-Phase l Aqueous/Organic:	16,650	0.6	0.51	\$44,490	\$6,000
Thin-File Evaporator	Aqueous Sludge	16,650-	0.020	0.02	\$1,400,000	\$460,000
Steam Stripping	: Two-Phase : :Aqueous/Organic:	16,650	0.6	0.6	\$85,000	\$76,000
CLOSING	LANDFILL (DBOH) -	- 3.5 acres	-			
C.Landfill 30 mil-HDPE	Aqueous Sludge	116,500	0.068	0.0678	\$60,370	\$9,000
	: Two-Phase : Aqueous/Organic:	116,500	2.09	1.03	\$60,370	\$9,000
C.Landfill 100 mil-HDPF	Aqueous E: Sludge	116,500	0.068	0.0679	\$155,720	\$23,000
	l Two-Phase Aqueous/Organic	116,500	2.09	1.77	\$155,720	\$23,000
Thin-Film Evaporator	Aqueous Sludge	116,500	0.068	0.07	\$9,900,000	\$3,290,000
Stean Stripping	¦ Two-Phase ¦Aqueous∕Organic	116,500	2.09	2.1	\$592,000	\$536,000
CLOSING	LANDFILL (D801) -	- 5 acres				
C.Landfill 30 mil-HDPE	Aqueous Sludge	166,500	0.0973	0.0970	\$86,250	\$13,000
	l Two-Phase Aqueous/Organic	166,500	2.89	1.42	\$86,250	\$13,000
C.Landfill 100 mil-HDP	l Aqueous El Sludge	166,500	0.0973	0.0972	\$222,450	\$33,000
	l Two-Phase Aqueous/Drganic	166,500	2.89	2.45	\$222,450	\$33,000
Thin-Film Evaporator	l Aqueous Sludge	166,500	0.097	0.10	\$14,100,000	\$4,690,000
Steam Stripping	: Two-Phase Aqueous/Organic	166,500	2.89	2.9	\$846,000	\$766,000

See notes at end of table.

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EMISSION Control	MODEL Waste type	ANNUAL THROUGHPUT (Mg/yr)	CI UNCONTROLLED Emissions (Mg/yr)	d: EMISSION REDUCTION (Mg/yr)	TOTAL Capital Investment	TOTAL Annual Costs
		COł	TAINER LOADING			
Tank Tru	ck Loading					
Submerged Fill Pipe	Aqueous Sludge	521	0.0045	0.003	\$390	\$70
	Dilute Aqueous-i	423	0.090B	0.059	\$390	\$70
	Organic Liquid	413	0.0169	0.011	\$390	\$70
	Organic Sludge/Slurry	499	0.0446	0.029	\$390	\$70
	Two-Phase Aqueous/Organic	490	0.0385	0.025	\$390	\$70

TABLE C-6. SUMMARY OF TSDF MODEL UNIT ANALYSIS RESULT^a

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See notes at end of table.

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TABLE C-6. SUMMARY OF TSDF MODEL UNIT ANALYSIS RESULTS^a (continued)

^aThis table summarizes the control costs and emission reductions by process unit for controlling organic air emissions from hazardous waste treatment, storage, and disposal facilities (TSDF). The control costs and achievable emission reductions were estimated through a model unit analysis utilizing a variety of diverse yet representative TSDF process model units, model waste compositions or forms, and applicable control technologies. The costs (in terms of \$/Mg of waste throughput) were then used to develop the control technology and cost file (Appendix D, Section D.2.5) that is used in combination with the TSDF Industry Profile (Appendix D, Section D.1.3) and the waste characterization data base (Appendix D, Section D.1.4) to estimate nationwide cost impacts for alternative control strategies.

The model wastes used in the determination of control costs and emission reduction in the model unit analysis may not necessarily be representative of all actual waste streams processed at existing facilities. However, to the extent possible, the composition and quantities of the actual waste streams processed at existing facilities were used in estimating nationwide emissions and emission reductions resulting from the alternative control strategies.

Please note that all costs presented in this table are in January 1986 dollars.

- b1. Carbon Adsorption--Two different carbon adsorption systems were examined for application as control devices. One system involves the use of fixed-bed, regenerable carbon adsorption units (FBCA); the other involves use of disposable carbon canisters. Both carbon canisters and fixed bed regenerable carbon systems were costed for each of the model unit/waste form cases; the less expensive system was selected for application. The fixed-bed carbon system's operating costs include the regeneration and eventual replacement and disposal of spent carbon; carbon canister's operating costs include carbon canister replacement and disposal. Carbon adsorption can reasonably be expected to achieve a 95-percent control efficiency for most organics under a wide variety of stream conditions provided (1) the adsorber is supplied with an adequate quantity of high quality activated carbon, (2) the gas stream receives appropriate conditioning (e.g., cooling, filtering) before entering the carbon bed, and (3) the carbon beds are regenerated or replaced before breakthrough.
- 2. <u>Internal Floating Roofs</u>--Emission reductions for internal floating roofs relative to a fixed-roof tank were estimated by using the emission models described in Appendix C, Section C.1.1.4.3 (fixed roof tank emissions) and EPA's Compilation of Air Pollutant Emission Factors (AP-42). Estimated emission reductions ranged from 74 to 82 percent. The variation in emission reductions is attributable to differences in composition and concentrations of model wastes.

Internal floating roofs are applied to uncovered vertical tanks in conjunction with a fixed roof to suppress the uncovered tank organic emissions. For this combination, the emission reductions achievable are a combination of the reduction from application of the fixed roof to the

TABLE C-6. SUMMARY OF TSDF MODEL UNIT ANALYSIS RESULTS^a (continued)

uncovered tank, plus application of an internal floating roof to a fixedroof tank. The range of emission reductions achievable based on combination of the fixed roof with the internal floating roof is 96 to 99.

- 3. <u>Existing Control Device</u>--Venting organic emissions to an existing control device is assumed to achieve an overall emission reduction of 95 percent; this includes both capture and control efficiencies.
- 4. <u>Fixed Roof</u>--Emission reductions for application of fixed roofs to uncovered tanks ranged from 25 to greater than 99 percent depending on waste form for both storage and treatment tanks.
- 5. <u>Membrane</u>--Floating synthetic membranes are applicable to quiescent impoundments and uncovered storage tanks. Emission reductions are determined by the fraction of surface area covered and by the permeability of the membrane. An emission reduction of 85 percent was used for floating synthetic membranes for purposes of estimating emission reductions from membrane-covered impoundments.
- 6. <u>ASP</u>--This control alternative involves installing an air-supported structure (ASP) and venting emissions to a carbon adsorption system. The efficiency of air-supported structures in reducing or suppressing emissions is determined by the combined effects of the capture efficiency of the structure and the removal efficiency of the control device. An overall control efficiency of 95 percent is used for air-supported structures vented to carbon adsorber.
- 7. <u>HDPE</u>--In this control technique, flexible covers are used to suppress or limit organic emissions from area sources. A typical cover material is 30-mil high-density polyethylene (HDPE). For the purposes of estimating emission reductions, control efficiencies of 0, 49.3, and 99.7 percent were used for 30-mil HDPE covers, depending on characteristics of the waste (i.e., permeability). Emission reductions of 0, 84.8, and 99.9 percent were selected for the model wastes with a 100-mil HDPE cover. The variations in emission reductions are attributable to differences in composition and concentrations of the model wastes.
- ^CUncontrolled emissions were estimated for each model unit and waste type using the appropriate TSDF air emission models as described in Section C.1; the model unit design and operating parameters described in Section C.2.1; and the waste compositions listed in Appendix C, Table C-5.

^dEmission reductions achievable through application of the emission control technologies are calculated on the basis of the control efficiencies presented in Chapter 4.0. These emission reductions can be grouped into three broad categories based on the technologies involved:

(1) Suppression Controls -- Emission reduction are achieved by controls that contain the organics within a confined area and prevent or limit volatilization of the organics. Unless used in combination with add-on control devices, the organics may be emitted from a TABLE C-6. SUMMARY OF TSDF MODEL UNIT ANALYSIS RESULTS^a (continued)

downstream TSDF waste management process. Suppression devices include internal floating roofs for covered or closed tanks and floating synthetic membranes for impoundments.

- (2) Add-on Controls--Emission reductions are achieved by add-on controls that adsorb, condense, or combust the volatile organics and as a result prevent their release to the atmosphere. Examples include fixed-bed carbon adsorbers, condensers, thermal or catalytic incinerators.
- (3) Removal Processes--Emission reductions are achieved by pretreatment of wastes to remove organics prior to processing at TSDF waste management unit. Organics removal technologies include thin-film evaporators and steam strippers, batch distillation, and rotary kiln incinerators.

^eThe total capital investment and total annual costs for the Container Loading Model Units are the same for drum loading, tank truck loading, and rail tank car loading. In Table C-6, the emission control refers to the control technologies described in Chapter 4.0. Model units and their annual throughputs are those described in Section C.2.1. Model wastes are as defined in Section C.2.2. Uncontrolled emissions are estimates generated by the applicable emission model described in Section C.1.1. The emission reduction is calculated on the basis of efficiencies presented in Chapter 4.0 for each control technology. The costs of add-on and suppression-type controls are calculated as described in Appendix H and the accompanying control cost document.⁷¹ Appendix I presents information regarding the costing of organic removal processes and hazardous waste incineration.

The emission estimates in Table C-6 show the wide range of emission levels possible from a given model waste management model unit when wastes of different compositions and forms are managed in that unit. The table also shows that control costs for certain controls are independent of waste composition, e.g., fixed roof for storage tanks and floating synthetic membranes. At the opposite extreme, the costs for fixed-bed carbon adsorption controls (e.g., those applied to uncovered, aerated treatment tanks model unit TO1G) are highly sensitive to composition; i.e., bed size is a function of the level or quantity of uncontrolled emissions.

The emission reductions reported in Table C-6 are achieved through application of control technologies that can be classified into three broad categories based on the control mechanisms. Suppression controls contain the organics within a confined area and prevent or limit volatilization. Add-on controls are typically conventional air pollution control devices that adsorb, condense, or thermally destroy the volatile organics to prevent release to the atmosphere. Removal technologies involve pretreatment of wastes to remove organics prior to processing in TSDF waste management units.

The footnotes to Table C-6 explain an important point about the reported emission reductions. Controls, such as a fixed roof applied to a storage tank, suppress organic emissions from that tank by the amount indicated in the table. The emissions prevented by installation of a fixed roof may escape from the waste at some downstream waste processing step unless emissions from that downstream process are also controlled. The emission reductions achieved through suppression controls are truly

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emission reductions only if the suppressed emissions are prevented from escaping the waste processes at other downstream processing steps. Add-on controls such as carbon adsorption and incineration, biological decay to less volatile compounds, and/or organic removal from the waste stream are the principal approaches to avoid ultimate discharge to the atmosphere.

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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 (strategies) 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 (strategies). 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.

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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

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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 contains the composition of chemical constituents and their respective concentrations. 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. For each waste code, the WCDB provides the quantities reported in the Westat Survey data base by the physical and chemical form of the waste code. This quantitative distribution of physical/chemical forms within a waste code is then used to subdivide the TSDF's waste code quantity from the Industry Profile. Waste composition is used to estimate emissions on the basis of concentration and volatility. 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. 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

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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 cutoff value to determine if controls are to be applied to the waste stream. If the waste stream exceeds the VO cutoff, 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, volatility class, and identified facility as well as 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 also calculated. These are the environmental impacts that result from implementation of the air pollution control strategy (e.g., solid wastes generated through use of control techniques such as carbon adsorption and incineration). For cost, crossmedia, and secondary impacts, the SAM calculates control option impacts 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 national throughput for the management unit by the appropriate impact factor results in an estimate of the impact for the particular unit.

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/ μ g/m³/person). The SAM facility-specific indidence and risk coefficients can be scaled by actual annual facility emissions and the appropriate unit risk factor to give facility-specific health impact estimates that reflect the level of emissions resulting from a particular emission scenario or control strategy. 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 <u>Introduction</u>. 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 <u>Data Base Contents</u>. 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 OHDOOOOOOOOO (variable FCID). Its primary SIC code is designated as 2879 (SIC1, Pesticides and Agricultural Chemicals).

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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/vr)
OTYSTR	Amount of waste stored (Mg/vr)
TYPSTR	<pre>Storage process(es) - one of 20 potential process combina- tions^b</pre>
ΟΤΥΤΧ	Amount of waste treated (Mg/yr)
ΤΥΡΤΧ	Treatment process(es) - one of 19 potential process combinations ^b
OTYDIS	Amount of waste disposed (Mg/vr)
TYPDIS	Disposal process(es) - one of 11 potential process combi- nations ^D
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 = Reso	Durce Conservation and Recovery Act.

Mg = Megagrams.

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

^bHazardous waste management process combinations are presented in Table D-3.

Variable	Contents	
FCID SICC1 WSTCDE WAMT QTYSTR TYPSTR QTYTX TYPTX QTYDIS	OHDO0000000 3879 D001b 1056954 1056954 1 1056954 10 0	
TYPDIS SOURCE ELIGSTAT LATT LONG	0 2 7 3115000 08758000	

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

^aAn example record of how one facility waste stream would appear in the Industry Profile data base.

^bD001 = ignitible waste. Source: 40 CFR 261.21, Characteristic of ignitibility.⁵

Ignitible wastes identified as DOO1 (WSTCDE) are managed at this facility. This TSDF manages (WAMT) and stores (OTYSTR) 1,056,954 Mg of waste D001 in a tank (TYPSTR = 1--see Table D-3), but it also treats the same amount (OTYTX = 1.056.954 Mg) in a tank (TYPTX = 10--see Table D-3). No guantity of this waste is disposed of (OTYDIS and TYPDIS, respectively). The data source for the RCRA waste code, its fraction of the total TSDF waste guantity, 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 (TO1), surface impoundment (TO2), incinerator (TO3), or other process (TO4)
- 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 TO4 ("other treatment") is listed separately, but its emissions are calculated on the basis of TO1 (treatment tanks) operation. TO3 (incineration) and D79 (injection well) are listed, but the SAM only calculates their transfer

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Combination number	Process code description ^C	Waste flow used in modeling simulation
Storage Proce	esses (variable TYPSTR in Table D-1)	
0	No storage	No Storage
1	SO2 only	→ S02
2	SO1 only	→ S01
3	SO4 only	→ S04
4	SO3 only	→ \$03
5	Other storage	→ S01
6	S01, S02	→ S01 → S02
7	SO1, SO4	→ SO1 → SO4
8	S01, S02, S03	$\downarrow \Box S01 \rightarrow S02$
9	S01, S03	+ SO1 + SO3
10	S01, S02, S04	+ SO1 → SO2 → SO4
11b	S01, S04	→ C, S01 S04
12b	S01, S03, S04	+ C SO1 + SO4
13b	SO4, sump	→ \$04
14b	SO2, other	+ SO2 + SO1
15	SO3, SO4	→ C→ S03 S04
16	S02, S03	→ C→ SO2 SO3
17b	S02, S03, S04	→ E SO2 SO3 SO4

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

See notes at end of table.

Combination number	Process code description ^C	Waste flow used in modeling simulation
Storage Processes	(con.)	
18	SO2, SO4	+ C, S02 S04
19b	SO1, SO2, SO3, SO4	$\rightarrow \stackrel{SO1}{\underset{SO3}{\overset{SO1}{\underset{SO4}{}{}}}} \stackrel{SO2}{\underset{SO4}{\overset{SO2}{}}}$
20	S01, S02	→ C, SO1 SO2
Treatment Process	es (variable TYPTX in Table D-1)	
0	No treatment	No treatment
1	T01 only	→ T01
2	TO2 only	→ T02
3	TO3 only	→ T03
4	TO4 only	→ T04
5	T01, T02	→ T01 → T02
6 ^b	T01, other	÷ T01 → T04
7b	T01, other	→ T01 → T04
8	T01, T03	→ C T01 T03
9b	TO3, other	+ ☐ ^{T03} T04
10	T01, T02, T03	$\overrightarrow{T}_{T03} \xrightarrow{T01} \overrightarrow{T}_{T02}$
11 ^b	T01, T03, other	$ \stackrel{\text{TO1}}{} \stackrel{\text{TO4}}{} \stackrel{\text{TO4}}{} $
12	T02, T03	+ C T02 T03
13	T02, T04	+ T02 → T04

TABLE D-3 (continued)

See notes at end of table.

Combination number	Process code description ^C	Waste flow used in modeling simulation
Treatment Process	ses (con.)	
14 ^b	T01, T02, T03, T04	$_{} } _{} _{} _{} _{} _{} } _{} _{} _{} } _{} } _{} } _{} } _{} } } } } } $
15	T01, T04	→ T01 → T04
16	T03, T04	→ C→ T03 T04
17	T01, T02, T04	→ T01 → T02 → T04
18	T01, T03, T04	$\downarrow \downarrow \downarrow 101 \rightarrow 103$
19	T02, T03, T04	$\downarrow \downarrow 102 \rightarrow 104$
Disposal Processe	s (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	→ C, D81 D83
7	D80, D83	→ C, D80 D83
8p	D79, D83	→ C→ D79 D83
дb	D79, D81	→ C→ D79 D81
10	D80, D81	→ C, D80 D81

TABLE D-3 (continued)

See notes at end of table.

Combination	Process code	Waste flow used
number	description ^C	in modeling simulation
Disposal Processes	5 (con.)	
11	D79, D80	+ C→ D79 D80
^a This table preser	nts the various combinations	of processes a waste code may
pass through at a	a facility. Column 3 depict	s how waste code combinations ar
interpreted to si	imulate actual facility proc	essing steps in the Source
Assessment Model.	. In many cases, it is unli	kelv that processes occur in

TABLE D-3 (continued)

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.

^bSources currently are not found in the Industry Profile data base but could potentially occur.

^CProcess code descriptions:⁶

Storage

	<u> </u>		<u> </u>	
SO1 Container	T01	Tank	D79	Injection well
SO2 Tank	T02	Surface impoundment	D80	Landfill
SO3 Wastepile	T03	Incinerator	D81	Land treatment
SO4 Surface impoundment	T04	Other	D83	Surface impoundment

Disposal

Treatment

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 <u>Code of Federal Regulations</u> (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 <u>Establishing the SAM Universe of TSDF</u>. 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 <u>Data Sources</u>. 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.

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

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

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

^aThis 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 <u>HWDMS</u>. 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

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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 <u>SIC codes development</u>. 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 Manufactures¹⁹ 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 <u>TSDF Waste Characterization Data Base (WCDB)</u>

D.2.2.1 <u>Background</u>. 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 sources²² (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 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 <u>Application to the Source Assessment Model (SAM)</u>. 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.

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

SIC code	4953			
Form code ^b	4XX			
RCRA characteristic code ^{c,d}	Т			
RCRA waste code ^d	U108			
Waste constituent/% composition	1,4-Dioxane/90%			
	Water/10%			
SIC = Standard industrial classi RCRA = Resource Conservation and	fication. Recovery Act.			
^a This table presents an example of Characterization Data Base for of industry.	of the information found in the Waste one waste stream managed in a given			
^b Physical/chemical waste forms a	re coded as follows:			
1XX = Inorganic solid4XX = Organic liquid2XX = Aqueous sludge5XX = Organic sludge3XX = Aqueous liquid6XX = Miscellaneous.				
^C RCRA characteristic code reflec	ts the hazard of the waste:			
T = Toxic C = Corrosive I = Ignitible R = Reactive.				

dRCRA characteristic and waste codes listed in 40 CFR 261.33(f).²⁶

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

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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 guantitative 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 <u>Limitations of the WCDB</u>. 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 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 261²⁷ 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 <u>Westat Survey Data Base</u>. 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 <u>Use of the Westat data base</u>. 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:

- <u>SIC code</u>--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.)
- <u>RCRA waste code</u>--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.
- <u>Physical/chemical waste form</u>--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.

• <u>Physical/chemical waste form quantity</u>--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 <u>Westat Survey Data Base limitations</u>. 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 <u>Industry Studies Data Base</u>. 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 <u>Use of the ISDB</u>. 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 <u>ISDB limitations</u>. 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 <u>New Field Test Data</u>.

D.2.2.6.1 <u>Data base description</u>. This data base is a collection of waste composition data developed from the review of a hazardous waste TSDF process sampling report²⁸ 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 <u>Use of the data base</u>. 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 <u>Data base limitations</u>. 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 <u>Data base description</u>. 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.

SIC code	Industry	Waste code ^b	Waste form ^C
3471	Electroplating	D002	3XXq
3728	Aircraft Parts	D002	3XXq
2911	Petroleum Refining	D002	3XXq
2911	Petroleum Refining	D006	2XX
2911	Petroleum Refining	D007	2XX
2911	Petroleum Refining	К048	5XX
2911	Petroleum Refining	КО49	5XX
2911	Petroleum Refining	K051	5XX
2911	Petroleum Refining	к052	2XX

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

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

^aThis 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.

^bWaste 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

^CPhysical/chemical waste forms are coded as follows:

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

^dThe field data contained only a very small percentage of organic constituents; therefore, these organics were inserted into the existing WCDB compositions, normalizing the original³⁵ organics to maintain the original total organic percent composition.

D.2.2.7.2 <u>Use of the data base</u>. 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 <u>Data base limitations</u>. 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 <u>Million Dollar Directory³⁶</u> 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 <u>Use of the data base</u>. The original K waste code data base developed by Environ³⁷ 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, Radian³⁸ 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 <u>K Stream data base limitations</u>. Although this data base contained compositional information on each RCRA K stream, it had two limi-tations:

- 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.

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D.2.2.9 WET Model Data Base.

D.2.2.9.1 <u>Data base description</u>. 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 <u>Use of the data base</u>. The WCDB uses the following WET data:

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

D.2.2.9.3 <u>WET data base limitations</u>. 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 <u>WCDB Waste Composition Defaults</u>. 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 DOO1/waste form, DOO2/waste form, DQO3/waste form, and DXXX (i.e., DOO4-DO17)/waste form. For example, if the ISDB had compositions of DOO1/4XX from four SIC codes, the four sets of compositions were composited to create one DOO1/4XX default composition. Each time the SAM finds a TSDF managing DOO1/4XX 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 back-ground document⁴¹ 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 principles⁴⁵ were applied:

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

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

^aThis 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. ^bWaste 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 <u>Organic Concentration Limits</u>. 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., FOO1--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.

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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	ΝΑ
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

TABLE D-8. DEFAULT STREAM COMPOSITIONS FOR WASTE CODES F001 TO F005a

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	ΝΑ
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 benzene 0.57% Butanol 0.12% Cyclohexanone

TABLE D-8 (continued)

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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 isobutyl ketone 0.81% 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 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

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
	бXX	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

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			

TABLE D-8 (continued)

NA = Not applicable.

^aThis table presents default waste stream compositions derived from WET model waste stream data⁴⁷ 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.

^bWaste codes listed in 40 CFR 261.31, Hazardous wastes from non-specific sources.⁴⁸

^CPhysical/chemical waste forms are coded as follows:

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

	Organic concentration limit, %			
Waste code ^b	Wastewaters (waste form 3XX)	Aqueous sludges (waste form 2XX)		
PC	1%	1%		
UC	1%	1%		
F001-F005	1% ^d	1% ^C		
KC,e	1%	1%		
D001 ^c ,f	5%	5%		
D002f	0.4%9	0.4%C		
D003 ^f	6%C	6%9		
D004 and greater ^{c,f}	0.1%	0.1%		

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

^aThis 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.

- ^bWaste 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
- ^CSource: Best engineering judgment based on review of waste code descriptions. (Nonconfidential Industry Studies Data Base data are inadequate or do not exist.)
- ^dSource: Land disposal restrictions regulatory impact analysis.⁵²
- ^eConcentration 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

^fConcentration 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.

gSource: 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 <u>FOO1 to FOO5 (spent solvent)</u>. 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 Survey⁵⁵ 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 <u>D001</u>. 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 <u>D002, D003, and D004 to D017 (DXXX)</u>. 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 <u>Introduction</u>. 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 <u>Waste Characteristics Affecting Emissions</u>. 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

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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 report⁵⁷ 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 particulateassociated). Important physical/chemical factors to consider when assessing the volatilization of a waste constituent include:

- <u>Water solubility</u>. 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.
- <u>Vapor pressure</u>. 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.
- <u>Partial pressure</u>. 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.
- <u>Henry's law constant</u>. 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.
- <u>Raoult's law</u>. 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 <u>Waste properties--physical and chemical</u>. 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 <u>Vapor pressure categories</u>. 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 document⁶⁰ divided vapor pressures into three useful categories: high (>1.33 kilopascals [kPa]), moderate (1.33 x 10^{-4} to 1.33 kPa), and low (<1.33 x 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.

	Henry's law				Surrogate category ^c	
	Vapor pressure.	constant, -3 3 10 kPa®m /g	Biorate.	Biodegradability	Vapor	Henry's law
Compound name	kPa	mol	mg VO/g/h	category	pressure	constant
Acetaldehyde	122	9.6	82.4	High	10	4
Mathyl ethyl ketone	13.3	4.4	73.8	High	1	4
Toluene	3.99	675	73.5	Hìgh	1	1
Acrylonitrile	15.2	8.9	44.30	Hìgh	1	4
Pyridine	2.02	2.4	35.03	High	1	4
Pheno I	0.045	0.0459	33.6	High	4	7
Butano I-1	Ø.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	Ø.3	23.2	Hìgh	4	7
Cresol (-p)	0.015	Ø.3	23.2	High	4	7
Cresols	0.019	Ø.3	23.2	Hìgh	4	7
Cresol (-o)	Ø.032	Ø.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	62.7	17.8	High	4	4
Ethyl acetate	11.3	12.9	17.6	High	1	4
Cresvlic acid	0.04	Ø.2	15.00	Hiah	4	7

TABLE D-10. DATA USED FOR WASTE CONSTITUENT CATEGORIZATION AND SURROGATE PROPERTY SELECTION IN THE SOURCE ASSESSMENT MODEL*, $^{\rm b}$

See notes at end of table.

	Vapor	Henry's law				Surrogate <u>category^c</u> Henry's
Compound name	pressure, kPa	-3 3 10 kPa•m /g mol	Biorate, mg VO/g/h	Biodegradability category	Vapor pressure	law constant
Acetone	35.4	2.5	14.6	High	2	5
Methanol	15.2	Ø.3	12.00	High	1	7
Cyclohexanone	Ø.64	0.4	11.5	High	4	7
Dichlorobenzene (1,2) (~o)	0.2	198	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	Ø.3Ø2	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	Ø.74	Low	6	6
Allyl alcohol	3.098	NA	NÂ	Moderate	2	8
Carbon disulfide	48,7	1,212	NA	Moderate	2	2
Carbon tetrachloride	15,03	3,030	NA	Low	3	3
Chłoroprene	36.3	NA	NA	Low	3	NA
Cumene (isopropylbenzene)	0.612	1,480	NA	Moderate	Б	2
Dichlorobenzene (1,4) (-p)	0.16	162	NA	Moderate	Б	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

TABLE D-10 (continued)

(continued)

a

		Nonnuto low			Surrogate	
Compound name	Vapor pressure, kPa	constant, 3 10 kPa®m /g mol	Biorste, mg VO/g/h	Biodegradability category	Vapor pressure	Henry's law constant
thylene oxide	166	3.7	NA	High	10	4
reons	NA	NA	NA	Low	NA	NA
exachlorobutadiene	0.02	2,590	NA	Low	6	3
exachlorocyclopentadiene	0.0108	1,620	NA	Low	6	3
aphthalene	0.031	119	NA	Moderate	5	2
itrosomorpholine	NA	NA	NA	Low	NĂ	NA
hosgene	185	17,300	NA	Low	12	3
hthalic anhydride	0.0002	Ø.1	NA	High	4	7
olychlorinated biphenyls	NA	20.2	NA	Low	NA	NA
roplyene oxide	69.2	19.4	NA	High	1	4
etrachloroethane (1,1,2,2)	Ø.864	38.4	NA	Low	6	6
etrachloroethylene	2.53	NA	NA	Low	3	3
richloro (1,1,2) trifluoroe	thane	119	NA	Low	3	3
ichloroethane (1,1,1)	16.4	8,081	NA	Low	3	3
richloroethylene	9.97	919	NA	Low	3	3
richlorofluoromethane	105.8	5,890	NA	Low	3	3
inyl chloride	354	8,690	NA	Low	12	3
inylidene chloride	78.6	19,200	NA	Low	3	3
ylene (-o)	Ø.931	618	NA	High	1	1

TABLE D-10 (continued)

NA = Not available.

VO = Volatile organics.

^aThis table provides the primary data for 60 chemicals used in developing surrogate categories to be used in the Source Assessment Model. Source of data: Research Triangle Institute. CHEMDAT3 Database for Predicting VD Emissions from Hazardous Waste

^bSource 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. 1986.⁵⁹

cRefers 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.^{61,62,63}

D.2.3.3.1.2 <u>Henry's law categories</u>. 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 (<10⁻³ kPa m³/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 m³/g mol, rapid volatilization will generally occur. A number of citations found in the literature support the Henry's law constant volatilization categories selected.^{64,65} Henry's law constants were grouped as follows:

- High $>10^{-1}$, kPa m³/g mol
- Moderate 10^{-1} to 10^{-3} , kPa m³/g mol
- Low $<10^{-3}$, kPa m³/g mol.

D.2.3.3.1.3 <u>Biodegradation categories</u>. 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.⁶⁶ In some cases, the biodegradation rate was inconsistent with values reported elsewhere for measures such as BOD₅, 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 <u>Surrogate categories</u>. 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.67

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

	Surrogate	Const	ituent pro	perties
	category	VPp	HLCC	Bio ^d
Vapor Pressure	1	Н	NA	Н
Surrogates	2	Н	NA	М
	3	Н	NA	L
	4	М	NA	Н
	5	М	NA	Μ
	6	М	NA	L
	7	L	NA	Н
	8	L	NA	Μ
	9	L	NA	L
	10	VH	NA	Н
	11	VH	NA	М
	12	VH	NA	L
Henry's Law	1	NA	Н	н
Constant Surrogates	2	NA	Н	Μ
	3	NA	Н	L
	4	NA	М	Н
	5	NA	М	М
	6	NA	М	L
	7	NA	L	Н
	8	NA	L	Μ
	9	NA	L	L

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

NA = Not applicable.

^aThis table describes the volatility and biodegradation properties of each waste constituent (surrogate) category developed for use in the Source Assessment Model.

рур :	= Vapor	pressure categories:	aBio =	Biodegradation rates:
VH	= Very	high (>101.06 kPa).	H =	High (>10 mg VO/g biomass/h).
Н	= Higȟ	(1.33-101.06 kPa).	M =	Moderate (1-10 mg VO/g
М	= Moder	rate (1.33x10 ⁻⁴ -1.33 kPa)	•	biomass/h).
L	= Low	(<1.33x10 ⁻⁴ kPa).	L =	Low (<1 mg VO/g biomass/h).

CHLC = 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).

Surrogate category ^b	М.₩.	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.Ø	34	9.63	89.9	0.30
MVHB (4)	111.0	Ø.346	9.02	76.8	22.60
MVMB (5)	132.0	0.266	7.50	84.3	3.02
MVLB (6)	185.0	Ø.386	7.32	66.9	0.39
LVMB (8)	98.0	1.33 x 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

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

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.

^aProperties 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.⁶⁸

^bNot 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.

Surrogate category	M.W.	Diff. water, cm ² /s (10 ⁻⁸)	Diff. air, cm ² /s (10 ⁻³)	Biorate, mg VO/g/h	× _{V0C} (10 ⁻³)	Temperature adjustment equation ^b	H-law const. 298 K ^c (10 ⁻⁶)
MHLB (6)	112.0	8.60	76.4	Ø.39	3.27	$H = \bullet[(-4879.12/T) + 17.1726]/1*10^{5}$	22.2
HHLB (3)	144.0	9.39	87.6	Ø.3Ø2	2.54	$H = \bullet[(-2275.36/T) + 15.6418]/1*10^{5}$	30,000
LHMB (8)	78.4	11.3	180	3.55	4.66	$H = \bullet[(-11562.27/T) + 23.14]$	Ø.158
MHMB (5)	57.0	11.8	115	11.2	6.40	$H = e[(-4090.15/T) + 15.13143]/1*10^5$	40.8
HHMB (2)	117.0	8.24	74	2.71	3.13	$H = e[(-5462.87/T) + 23.10247]/1*10^{5}$	1,180
LHHB (7)	97.3	9.64	82.7	23.2	3.76	$H = \bullet[(-11562.27/T) + 23.14]$	Ø.158
MHHB (4)	69.9	11.8	95.6	40.1	5.23	$H = \bullet[(-3256.36/T) + 12.84471]/1*10^{5}$	Ø.68
HHHB (1)	98.4	9.40	87.3	29.2	3.72	$H = \bullet[(-3180.14/T) + 16.95871]/1 + 10^{5}$	5,380

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

X = Mole fraction of volatile organic compounds (VOC).

V0 = 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 x 10^{-2} for all surrogate categories.

^aThis 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.⁶⁹

 $^{
m C}$ Henry's law constants at 25 $^{
m o}$ C (298 K) are those used in emission models; see Appendix C.

b Henry's law constant units are Kpa • m /g mol. The equation predicts Henry's law constant for a range of temperatures for each category.
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: 70,71 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 poly-Biodegradation assignments were based on quantitative measures, mers. although largely unavailable, or on a comparison of molecular structure with chemicals well characterized by biodegradation.⁷² 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.

|--|

		Classification	
Parameter	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

BOD₅ = 5-day biochemical oxygen demand.

^aThis 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 bio-degradation 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 <u>Introduction</u>. 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 report⁷³ 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.

Emission Models. The emission factors used for estimating D.2.4.2 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, final edition of the air emission models report has been 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 draft to the December final version affect, 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.

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. Longterm 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, an emission estimate was generated for each chemical surrogate category for each management process. Process parameters and surrogate properties used to estimate emission factors are presented in Table D-15. Emission estimates generally were calculated on a mass-perunit-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. Multiple model units (described in Appendix C) were developed for each waste management process to span the range of nationwide design characteristics and operating parameters (surface area, waste throughputs, detention time, etc.). Because these particular characteristics were generally not available for sitespecific estimates, it was necessary to develop a "national average model unit" to represent each waste management process. This was accomplished by generating a set of weighting factors for each TSDF waste management process based on frequency distributions of quantity processed, unit size, or unit area that were 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. 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

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TABLE D-15.	HAZARDOUS	WASTE MA	NAGEMENT	PROCESS	PARAMETERS	AND WASTE
CONSTITUE	ENT PROPER	TIES USED) TO ESTI	MATE EMIS	SSION FACTO	RS FOR
		SOURCE AS	SESSMENT	MODELa		

Waste management process	Physical/chemical waste form	Surrogate group	Waste organic concentration
Covered tank storage (SO2)	Organic liquid	Vapor pressure	Pure component
Uncovered tank storage (SO2)	Aqueous liquid	Henry's law	1,000 ppm
Storage impoundments (SO4)	Aqueous liquid	Henry's law	1,000 ppm
Covered quiescent treatment tanks (TO1)	Aqueous liquid	Henry's law	1,000 ppm
Uncovered quiescent treatment tanks (TO1)	Aqueous liquid	Henry's law	1,000 ppm
Uncovered aerated treatment tanks (TO1)	Aqueous liquid	Henry's law	1,000 ppm
Quiescent treatment impoundments (TO2)	Aqueous liquid	Henry's law	1,000 ppm
Aerated treatment impoundments (TO2)	Aqueous liquid	Henry's law	1,000 ppm
Disposal impoundments (D83)	Aqueous liquid	Henry's law	1,000 ppm
Terminal loading impoundments and tanks (LO1)	Aqueous liquid	Henry's law	1,000 ppm
Terminal loading storage tanks (LO3)	Organic liquid	Vapor pressure	Pure component
Wastepiles (SO3)	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	

^aThis 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. to predict biodegradation quantities; equations for biodegradation rate are presented in Appendix C. These TSDF emission factors were developed to present 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-16. 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) upper limit annual loss from pipeline transfer.

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 organic removal, land treatment alternatives, and add-on control alternatives among others. The control file is a combined file that includes control costs (see Appendixes H and I) as well as control efficiencies.

Tables D-17, 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

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	for (SØ1)	Weighted emi container a using vapor	ssion factor and drum stor pressure sur	s age rogates	We (SØ1) u	ighted emis for dumpst sing vapor	sion factors er storage pressure sur	rogetes	Weighted emission factors for covered tank storage (SØ2) 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	0.6771	1.0000	0,0001			0.0012	0.0000	0.0000	Ø.6771	
2		0.0001	0.0011	0.6771	1.0000	0.0001	:		0.0011	0.0000	0.0000	0.6771	
3		0.0001	0,0018	0.6771	1.0000	0.0001			0.0017	0,0000	0.0000	0.6771	
4		0.0001	0,0000	0.8771	0.4786	0.0001			0.0000	0.0000	0.0000	0.6771	
Б		0.0001	0.0000	0.2514	0.4014	0.0001			0.0000	0.0000	0.0000	0.2514	
6		0.0001	0.0000	0.2514	Ø.8269	0.0001			0.0000	0.0000	0.0000	0.2514	
7		0.0001	0.0000	0.2514	0.0000	0.0001			0.0000	0.0000	0.0000	Ø.2514	
8		0.0001	0,0000	0.2514	0.0000	0.0001			0.0000	0.0000	0.0000	0.2514	
9		0.0001	0.0000	Ø.2514	0.0000	0,0001			0.0000	0.0000	0.0000	Ø.2514	
10		0.0001	0.0069	Ø.6771	1.0000	0.0001			0.0000	0.0000	0.0000	0.6771	
11		0.0001	0.0140	Ø.8771	1.0000	0.0001			0.0000	0.0000	0.0000	0.6771	
12		0.0001	0.0140	Ø.6771	1.0000	0.0001			0.0000	0,0000	0.0000	0.6771	

TABLE D-16. EMISSION FACTOR FILES^{8, b}

	Weight e using	d emission f tank store Henry's law	actors for u ige (SØ2B) constant sur	ncovered rogates	(<u>5</u> 03) u	leighted emi for wa sing vapor	ssion factor stepiles pressure sur	s rogates	Weighted emission factors for storage impoundments (SØ4) using Henry's law 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	0.5510	0.0000		Ø.6771	0.0125	0.0000			0.7460	0.0000		3.6240
2	0.5450	0.0000		Ø.6771	0.0115	0.0000			0.7390	0.0000		3.6240
3	0.1180	0.0000		Ø.6771	0.0175	0.0000			0.0590	0.0000		1.0285
4	0.5480	0.0000		Ø.2514	0.0020	0.0000			0.7330	0.0000		3.6240
5	0.5410	0.0000		0.2514	0.0020	0.0000			0.7280	0.0000		1.0285
6	0.1680	0.0000		Ø.2514	0.0020	0.0000			0.0930	0.0000		3.6240
7	0.5510	0.0000		Ø.2514	0.0000	0.0000			0.7470	0.0000		3.6240
8	0.6460	0.0000		0.2514	0.0000	0.0000			0.6630	0.0000		1.0285
9	0.1680	0.0000		0.2514	0.0000	0.0000			0.0930	0.0000		3.6240
10					0.0275	0.0000						
11					0.0275	0.0000						
12					0.0275	0.0000						

	Weight qui using	ed emissio escent tre Henry's la	n factors fo atment tanks w constant s	r covered (TØ1) urrogates	Weighte qui using l	d emission escent trea Henry's law	factors for tment tanks constant s	r uncovered s (TØ1) surrogates	Weighted emission factors for uncovered aerated treatment tanks (T01) using Henry's law constant surrogates					
Surrogate	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	0.6771	0.1120	0.0000		Ø.8771	0.8780	0.0510	0.0000		Ø.6771	
2	0,0002	0.0000	0.0000	0.6771	0.0990	0.0000		0.6771	0.1450	0.4200	0.0000		0.6771	
3	0.0000	0.0000	0.0000	0.2514	0.0010	, 0.000 0		Ø.2514	0.0005	0.3100	0.0000		0.2514	
4	0.0022	0.0000	0.0000	0.8771	0.1060	0.0000		0.8771	0.7790	0.0110	0.0000		0.6771	
6	0.0002	0.0000	0.0000	0.2514	0.0910	0.0000		0.2514	0.1810	0.0020	0.0000		0.2514	
6	0.0000	0.0000	0.0000	0.2514	0.0030	0.0000		0.2514	0.0020	0.0550	0.0000		Ø.2514	
7	0.0422	0.0000	0.0000	0.6771	0.1120	0.0000		0.8771	0.9550	0.0000	0.0000		Ø.877	
8	0.0001	0,0000	0.0000	0.2514	0.0840	0.0000		Ø.2514	0.0940	0.0060	0.0000		Ø.2514	
9	0.0000	0.0000	0.0000	0.2514	0.0030	0.0000		0.2514	0.0020	0.0550	0.0000		0.251	

TABLE D-18 (continued)

	Weighted tr using H	emission eatment imp lenry's law	factors for poundments (constant su	quiescent TØ2) rrogates	Weighte in	ed emission poundments law con	factors f (TØ2) usi istant surr	or serated ng Henry's ogates		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		3.6240	0.7120	0.0830	0.0000		3.6240		0,0000		1.8430	
2	0.5080	0.0000		3.6240	0.3290	0.7700	0.0000		3.6240		0.0000		1.8430	
3	0.0170	0.0000		1.0280	0.0040	0.9150	0.0000		1.0280		0.0000		1.8430	
4	0.5000	0.0000		3.6240	Ø.978Ø	0.0010	0.0000		3.6240		0.0000		1.8430	
6	0.4910	0.0000		1.0280	0.8330	0.0060	0.0000		1.0280		0.0000		0.5140	
6	0.0260	0.0000		1.0280	0.0480	0.3190	0.0000		1.0280		0.0000		0.5140	
7	0.5190	0.0000		3.6240	0.9900	0.0000	0.0000		3.6240		0.0000		0.0000	
8	0.4090	0.0000		1.0280	0.7470	0.0040	0.0000		1.0280		0.0000		0,0000	
9	0.0260	0.0000		1.0280	0.0480	0.3180	0.0000		1.0280		0.0000		0.0000	
10									0.0000		0.0000		1.8430	
11									Ø.0000		0,0000		1.8430	
12									0.0000		0.0000		1.8430	

TABLE D-18 (continued)

See notes at end of table.

	W (D79)	eighted emis for injec using vapor	sions factor tion wells pressure sur	s rogates	Weighte usin	d emission active land ng vapor pre	factors for fills (D80) ssure surrog	onsite ates	Emission factors for onsite closed landfills (D80) 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		0.0000		1.8430	0.2230	0.0000			0.0091	0.0000			
2		0.0000		1.8430	0.2070	0.0000			0.0087	0.0000			
3		0.0000		1.8430	0.3110	0.0000			0.0171	0.0000			
4		0.0000		1.8430	0.0300	0.0000			0.0002	0.0000			
Б		0.0000		0.5140	0.0300	0.0000			0.0001	0.0000		·	
6		0.0000		0.5140	0,0410	0.0000			0.0003	0.0000			
7		0.0000		0.0000	0,0002	0.0000			0.0000	0,0000			
8		0.0000		0.0000	0,0002	0.0000			0.0000	0,0000			
9		0.0000		0.0000	0.0002	0.0000			0,0000	0.0000			
10		0.0000		1.8430	0.4870	0.0000			0.0435	0.0000			
11		0.0000		1.8430	0.7000	0.0000			0.0951	0,0000			
12		0.0000		1.8430	0.7000	0.0000			0.0951	0.0000			

TABLE D-18 (continued)

See notes at end of table.

	Weighted	emission fa active landf g vapor pres	actors for co ills (D80) sure surroga	mmercial tes	Weighte commerci	ad emission al landfill pressure	factors for s (D80) usin surrogates	closed ng vapor	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			0.0078	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	ø.øøøø [;]			1.0000	0,0000		~-
4	0.0160	0.0000			0.0001	0,0000			0.2663	0.0000		
Б	0.0150	0.0000		~-	0.0001	0.0000			Ø.3943	0.0000		
6	0.0210	0.0000			0.0002	0.0000			Ø.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			Ø.Ø367	0.0000			1.0000	0.0000		
11	0.3580	0.0000			0.0798	0.0000			1.0000	0.0000		
12	0.3560	0.0000			0.0798	0.0000			1.0000	0.0000		

TABLE D-16 (continued)

See notes at end of table.

	We sub: using	ighted em for land surface in vapor pro	ission fac treatment njection (essure sur	tors D81) rogates	Weigh disp usin	ted emiss osal impo g Henry's	ión factor undments (law surro	Weighted emission factors for terminal loading of containers (LØ1)			
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		3.6240	0.0001		0.0000
2	0.9640	0.0000			1.0000	0.0000		3.6240	0.0001		0.0000
3	0.9960	0.0000			0.4700	0.0000		1.0280	0.0001		0.0000
4	0.1510	0.0000			1.0000	0.0000		3.6240	0.0001		0.0000
Б	0.3310	0.0000			1.0000	0,0000		1.0280	0,0001		0.0000
6	0.8320	0.0000			0.6300	0.0000		1.0280	0.0001		0.0000
7	0.0020	0.0000			1.0000	0.0000		3.6240	0.0001		0.0000
8	0.0020	0.0000	~-		1.0000	0.0000		1.0280	0,0001		0.0000
9	0.0020	0.0000			0,6300	0.0000		1.0280	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

TABLE D-16 (continued)

	Weighte for ter impou (LØ2)	ed emission minal loadi undments and using Henry surrogates	factors ing from i tanks i's law	Weighte for ter storage vapor p	ed emission minal loadi tanks (LØ3 pressure sur	factors ng from) using rogates	Weighted emission factors for waste fixation using vapor pressure surrogates ^d				
Surrogate	f(sp)	f (loød)	k (fug)	f(sp)	f (load)	k(fug)	f(air)	f(sp)	f (load)	k (fug)	
1	0.0001	0.0013	0.0080	0.0000	0.0013	0.0080	0.6800	0.0000			
2	0.0001	0.0000	0.0080	0.0000	0.0013	0.0080	0.6800	0.0000			
3	0.0001	0.0000	0.0080	0.0000	0.0018	0.0080	0.6800	0.0000			
4	0.0001	0.0011	0.0080	0.0000	0.0000	0.0080	0.6800	0.0000			
5	0.0001	0.0000	0.0080	0.0000	0.0000	0.0080	0.6800	0.0000			
6	0.0001	0.0000	0.0080	0.0000	0.0000	0.0080	0.6800	0.0000			
7	0.0001	0.0018	0.0080	0.0000	0.0000	0.0080	0.6800	0.0000			
8	0.0001	0.0000	0.0080	0.0000	0.0000	0.0080	0.6800	0.0000			
9	0.0001	0.0000	0.0080	0.0000	0.0000	0.0080	0.6800	0.0000			
10				0.0000	0.0069	0.0080	0.6800	0.0000			
11				0.0000	0.0140	0.0080	0.6800	0.0000			
12				0.0000	0.0140	0.0080	0.6800	0.0000			

TABLE D-16 (continued)

Note: Dash indicates emission factors not applicable.

^BSome 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.

bThe f(___) in the column headings represent fractions emitted or degraded. The k(f) in the last column represents a constant emission rate or the upper limit emission rate in Mg/yr due to fugitive emissions:

- f(air) = process emissions fraction
- f(bio) = biodegradation fraction
- f(sp) = spills fraction
- k(f) =fugitives constant or limit.

CLoading emissions included in f(air).

^dEmission 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.

TSDF	TSDF		Vola- tilitv	Con- trol	Emission	Cont	Emission	incy	Trans- fer	Lond-	Ser-	Cost	To cap invest	tal ital iment, S	Cost func-	Ann oper cos	uel eting t, S
code (1)	emission source (2)	Weste form (3)	class (4)	index (5)	control option (6)	sion (7)	control (8)	Removal (9)	code (10)	ing (11)	life (12)	function (13)	(14)	ЬхQ (15)	tion (16)	• (17)	ЬхQ (18)
501	Drum Storage	VOC-cont Solid	A) 1	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	A11	i	Vent to Car Ads		35.00		C	A	20	Linear	0,00	72,000	Linear	0,00	21.000
501	Drum Storage	Dilute Aq	A11	1	Vent to Car Ads		95.00		C	Α	20	Linear	0.00	B9.000	Linear	0.00	27.000
501	Drum Storage	Org Liquid	A11	1	Vent to Car Ads		95.00		C	A	50	Linear	0,00	91.000	Linear	0.00	27,000
501	Drum Storage	Org Sidg/Slurry	A11	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	A11	1	Vent to Car Ads		95.00		C	A	20	Linear	0.00	91.000	Linear	0,00	27.000
501	Dumpster	VDC-cont Solid	A11	2	Dumpster Cover	99, 00					20	Linear	0,00	6.250	Linear	0.00	1.670
501	Dumpster	Aq Sidg/Siurry	A11	2	Dumpster Cover	99.00					20	Linear	0.00	9.375	Linear	0.00	2.500
S01	Dumpster	Dilute Aq	A]]	2	Dumpster Cover	99, 00					20	Linear	0.00	25.030	Linear	0.00	6.670
S01	Dumpster	Org Liquid	A11	2	Dumpster Cover	99.00					20	Linear	0.00	25.640	Linear	0.00	6. B40
501	Dumpster	Org 5)dg/Slurry	A11	2	Dumpster Cover	99, 00					20	Linear	0.00	17.850	Linear	0.00	4.980
S01	Dumpster	2-Phase Aq/Qrg	A11	2	Dumpster Cover	99.00					20	Linear	0, 00	25,610	Linear	0.00	6.B30
S01	Fugitives- Drum Load	Aq Sidg/Slurry	High	3					C								
501	Fugitives- Drum Load	Dilute Aq	High	3					C								
501	Fugitives- Dru∎ Load	2-Phase Aq/Ory	High	3					C								
501	Fugitives- Drum Load	Org Liquid	High	3					C								
501	Fugitives- Drum Load	Org Sldg/Slurry	High	3					С								
S01	Drum Loading	VOC-Cont Solid	A11	4					C	A							
SOI	Drum Loading	Aq Sldg/Slur	A11	4					C	A							
501	Drum Loading	Dil Aqueous	ALL	4					С	Α							
501	Drum Loading	Org Liquid	A11	4					С	A							
501	Drum Loading	Org Sidg/Slurry	A11	4					C	A							
501	Drum Loading	2-Phase Aq/Org	A11	4					C	A							
502	Tank Storage	Sub 2xx for 1xx	A11	1	IFR, CAds,Vent to C	D 84.5			D		10	Linear	0,00	9.740	Linear	0.00	3.290
502	Tank Storage	Aq Sldg/Slurry	A11	1	IFR, CAds, Vent to C	D 88,5			D		10	Linear	0,00	9,740	Linear	0.00	3, 290
S02	Tank Storage	Dilute Aq	A11	1	IFR, CAds, Vent to C	D 84.5			D		10	Linear	0.00	13.210	Linear	0.00	9,450
502	Tank Storage	Org Liquid	A11	1	IFR, CAds, Vent to C	D 91.75			D		10	Linear	0.00	12.360	Linear	0.00	4.720
502	Tank Storage	Org Sidg/Siurry	A11	1	IFR, CAds, Vent to C	D 91.5			D		10	Linear	0.00	11.080	Linear	0.00	5.710
502	Tarik Storage	2-Phase Aq/Org	A1 1	i	IFR, CAds, Vent to C	D 86.5			D		10	Linear	0.00	10.740	Linear	0.00	4, 870
\$02	Tank Storage	Sub 2xx for 1xx	A11	2	Fixed Roof	86.4			D		20	Linear	0.00	14.660	Linear	0.00	1.070
502	Tank Storage	Aq Sidq/Siurry	A11	2	Fixed Roof	98.70			D		20	Linear	0.00	14.660	Linear	0.00	1.070
502	Tank Storage	Dilute Aq	A11	2	Fixed Roof	86.40			D		20	Linear	0.00	18.470	Linear	0,00	1.360
502	Tank Storage	Org Liquid	Al 1	2	Fixed Roof	99, 90			D		20	Linear	0.00	18.590	Linear	0.00	1.370
	T . Ob	Due Clide (Clinese)	AL1	^	Fiund Boof	00.05			n		20	Lizoan	0.00	15 710	1.1	0.00	1 120

TABLE D-17.	SUPPRESSION /	AND ADD-0	N CONTROL	COST	FILE USED	BY	THE SOURCE	ASSESSMENT	MODEL ^{a,b}

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TSDF	Na		Vota-	Con-		Contr	ol efficie	ancy	Trans-		Ser-		То сар	tal ital	Cost	Ann oper	ual ating
code (1)	TSDF emission source (2)	Waste form (3)	tility class (4)	trol index (5)	Emission control option (6)	Suppres- sion (7)	Emission control (8)	Removal (9)	fer code (10)	Load- ing (11)	vice life (12)	Cost function (13)	* (14)	ы к Q (15)	func- tion (16)	(17)	5 × Q (19)
502	Tank Storage	2-Phase Aq/Drg	A11	2	Fixed Roof	90.00			Ð		20	Linear	0.00	15.720	Linear	0.00	1.160
502	Jank Storage	Sub 2xx for 1xx	A11	3	Roof, IFR, CAds, Vent	97.9			D		10	Linear	0.00	20, 980	Linear	0.00	3.980
502	Jank Storage	Ag Sidg/Slurry	A11	3	Roof, 1FR, CAds, Vent	99.85			Ð		10	Linear	0.00	20, 980	Linear	0,00	3, 980
S02	Tank Storage	Dilute Aq	A11	3	Roof, IFR, CAds, Vent	97, 90			D		10	Linear	0.00	27.660	Linear	0,00	10.500
502	Tank Storage	Org Liquid	A11	3	Roof, IFR, CAds, Vent	99, 99			D		10	Linear	0.00	26.840	Linear	0.00	6.150
502	Tank Storage	Ore Side/Slurry	A11	3	Roof, IFR, CAds, Vent	99.99			D		10	Linear	0,00	22.780	Linear	0.00	6.330
502	Jank Storage	2-Phase Ag/Org	A11	3	Roof, IFR, Cads, Vent	98,70			D		10	Linear	0.00	22, 550	Linear	0.00	6.690
502	Funitives- Tank Load	Ao Sido/Slurry	High	4					D								
502	Funitives- Tank Load	Dilut Aq	High	4					D								
\$02	Fugitives- Tank Load	2-Phase Ag/Org	High	4					D								
502	Fugitives~ Tank Load	Ora Liquid	High	4					D								
502	Fupitives- Tank Load	Org Sidg/Slurry	High	4					D								
503	Waste Pile	Ag Sida/Sierry	A11	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	A11	1	HD Cover 30 mil	99.70					5	Linear	0.00	0.310	Linear	0.00	0.080
503	Waste Pile	Sub 7xx for 4xx	A11	1	ND Cover 30 mil	49.30					5	Linear	0.00	0.310	Linear	0,00	0.080
S03	Waste Pile	Sub 7xx for 5xx	A11	1	HD Cover 30 mil	49.30					5	Linear	0.00	0.310	Linear	0.00	0.080
503	Waste Pile	2-Phase Ag/Org	A11	1	HD Cover 30 mil	49.30					5	Linear	0,00	0. 310	Linear	0.00	0.080
S03	Waste Pile	VOC-cont Solid	A11	1	HD Cover 30 mil	49.30					5	Linear	0.00	0.310	Linear	0.00	0.080
504	Stor Impd Surface	Sub 2xx for 1xx	A11	1	Syn Membrane	85.00			I		10	Linear	0.00	1,850	Linear	0,00	0.240
504	Stor Impd Surface	Aq Sldg/Slurry	A11	1	Syn Membrane	85.00			I		10	Linear	0.00	1.850	Linear	0.00	0,240
504	Stor Impd Surface	Dilute Aq	A11	1	Syn Membrane	85.00			1		10	Linear	0.00	1.850	Linear	0.00	0.240
504	Stor Jupd Surface	Sub 2xx for 4xx	ALL	1	Syn Membrane	85.00			1		10	Linear	0,00	1.850	Linear	0.00	0.240
504	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
504	Stor Impd Surface	2-Phase Aq/Org	A11	1	Syn Membrane	85.00			1		10	Linear	0.00	1.850	Linear	0.00	0.240
504	Stor Impd Surface	Sub 2xx for 1xx	Al 1	2	Struct w Car Adsorp	95.00			1		10	Linear	0.00	10.760	Linear	0.00	3.030
S04	Stor Impd Surface	Aq Sldg/Slurry	A11	2	Struct w Car Adsorp	95.00			I		10	Linear	0.00	10.760	Linear	0.00	3.030
504	Stor Impd Surface	'Dilute Aq	A) I	2	Struct w Car Adsorp	95.00			1		10	Linear	0.00	9, 430	Linear	0.00	2.270
504	Stor Impd Surface	Sub 2xx for 4xx	A11	2	Struct w Car Adsorp	95.00			I		10	Linear	0.00	10.760	Linear	0.00	3.030
504	Stor Impd Surface	Bub 2xx for 5xx	A11	2	Struct w Car Adsorp	95.00			I		10	Linear	0.00	10, 760	Linear	0.00	3.030
504	Stor Impd Surface	2-Phase Aq/Org	A11	2	Struct w Car Adsorp	95.00			1		10	Linear	0.00	9.430	Linear	0.00	2.270
504	Fugitives- Imp Load	Aq Sidg/Slurry	High	3					I								
S04	Fugitives- Imp Load	Dilut Aq	High	3					1								
504	Fugitives- Imp Load	2-Phase Aq/Drg	High	3					1								

TABLE D-17 (continued)

TSDF			Vola-	Con-		Conti	ol officie	incy	Trans-		Ser-		Tot cepi	el tel	Cost	Ann oper	ual ating
code	TSDF emission source	Waste form	tility class	trol index	Emission control option	Suppres- sion	Emission control	Removal	fer code	Load- ing	vice life	Cost function	invest (14)	<u>ment, 5</u> b x Q (15)	func- tion (18)	• (17)	t, <u>s</u> b x Q
(1)		(3)	(•)	(8)	(6)	()	(8)	(8)	(10)	(11)	(12)	(13)	(1-)	(10)	(10)	(1)	(10)
504	Fugitives- Imp Load	Drg Liquid	High	3					I								
504	Fugitives- Imp Load	Org Sidg/Slurry	High	3					I								
101	Tank Surface	Sub 2xx for 1xx	A11	1	Fixed Roof	87.50			н		20	Linear	0.00	0, 380	Linear	0.00	0,030
TOI	Tarik Surface	Aq Sidg/Siurry	A11	1	Fixed Roof	98.20			н		20	Linear	0.00	0, 380	Linear	0.00	0.030
TOT	Tank Surface	Dilute Aq	A11	1	Fixed Roof	87.50			н		20	Linear	0.00	0.380	Linear	0.00	0,030
T01	Tank Surface	Org Liquid	AI 1	1	Fixed Roof	99.22			н		20	Linear	0.00	0.380	Linear	0.00	0,030
TOI	Tank Surface	Org Sldg/Slurry	A11	1	Fixed Roof	38.99			н		20	Linear	0.00	0, 380	Linear	0.00	0.030
TOI	Tank Surface	2-Phase Aq/Org	A))	1	Fixed Roof	93.50			н		20	Linear	0.00	0.380	Linear	0,00	0,030
T01	Tank Surface	Sub 2xx for 1xx	A11	2	Roof, IFR, CAds, Vent	95.40			н		10	Linear	0.00	0.570	Linear	0.00	0.130
T01	Tank Surface	Aq Sldg/Slurry	A11	2	Roof, IFR, CAds, Vent	99, 70			н		10	Linear	0.00	0,570	Linear	0.00	0.130
TOI	Tank Surface	Dilute Aq	A11	2	Roof, IFR, CAds, Vent	95.40			н		10	Linear	0.00	1.160	Linear	0.00	0.390
T01	Tank Surface	Org Liquid	A11	2	Roof, IFR, CAds, Vent	99.96			н		10	Linear	0.00	0.710	Linear	0.00	0.280
TOI	Tank Surface	Drg 51dg/Slurry	A11	2	Roof, IFR, CAds, Vent	99.95			н		10	Linear	0.00	0. B00	Linear	0.00	0.300
T01	Tank Surface	2-Phase Aq/Drg	A11	2	Roof, IFR, Cads, Vent	97.10			н		10	Linear	0.00	0,800	Linear	0.00	0.360
T01	Tank Surface	Sub 2xx for 1xx	A11	3	IFR, CAds, Vent to CD	84.50			н		10	Linear	0,00	0.220	Linear	0.00	0.10
TOI	Tank Surface	Ag Sidg/Slurry	A11	3	IFR, CAds, Vent to CD	88,50			н		10	Linear	0.00	0,220	Linear	0,00	0.10
TOI	Tank Surface	Dilute Aq	A11	3	IFR, CAds, Vent to CD	84,50			н		10	Linear	0.00	0.820	Linear	0.00	0.37
TOI	Tank Surface	Ora Liquid	A11	3	IFR, CAds, Vent to CD	91.75			н		10	Linear	0.00	0.360	Linear	0.00	0.25
T01	Tank Surface	Org Sldg/Slurry	A11	3	JFR, Cads, Vent to CD	91.50			н		10	Linear	0.00	0,360	Linear	0.00	0.27
TOI	Tank Surface	2-Fhase Aq/Org	A11	3	IFR, Cads, Vent to CD	86.50			н		10	Linear	0.00	0.800	Linear	0.00	0.36
T01	Tank Surface	Sub 2xx for 1xx	A11	4	Roof, Vent to CAds	95.00			G		10	Linear	0.00	0.410	Linear	0.00	0.19
T01	Tank Surface	Ag 51dg/Sturry	A11	4	Roof, Vent to CAds	95,00			G		10	Linear	0,00	0.410	Linear	0.00	0.19
T01	Tank Surface	Dilute Ag	A11	4	Roof, Vent to CAds	95.00			6		10	Linear	0.00	0.420	Linear	0.00	0.30
T01	Tank Surface	Sub 2xx for 4xx	A11	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	A11	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	A11	4	Roof, Vent to CAds	95.00			G		10	Linear	0.00	0.410	Linear	0,00	0.19
T01	Funitives- @ Tank Ld	An Sida/Slurry	Hiah	5	•				н								
T01	Funitives- Q Tank Ld	Dilut Aq	High	5					н								
T01	Funitives- Q Tank Ld	Ora Sida/Slurry	High	5					н								
T01	Fugitives- Q Tank Ld	Ora Liquid	High	5					н								
T01	Funitives- Q Tark Ld	Ora Slde/Slurry	High	5					н								
TOI	Fugitives- A Tank Ld	Ao Sido/Slurry	High	6					G								
TOT	Funitives- A Tank Ld	Dilut Ao	Hinh	6					6								
TOI	Funitives- A Tank Ld	2-Phase An/Orn	High	6					6								
101	ragrestes in talk co	s , more reports															

TABLE D-17 (continued)

TSDF			Vola-	Con-		Conti	ol offici	ency	Trans-		Ser-		То сар	tal ital	Cost	Аплорег	ual ating
process code (1)	TSDF emission source (2)	Waste form (3)	tility class (4)	troi index (5)	Emission control option (6)	Suppres- sion (7)	Emission control (8)	Removel (9)	fer code (10)	Load- ing (11)	vice life (12)	Cost function (13)	<u>inves</u> a (14)	<u>tment, 9</u> b×Q (15)	func- tion (16)	(17)	<u>t, s</u> b x Q (18)
T01	Funitives- A Tank Ld	Org Liquid	High	6					G								
T01	Fugitives- A Tank Ld	Org Sldg/Slurry	High	6					G								
102	Treat Impd Surface	Sub 2xx for 1xx	A11	1	Stuct Car Adsorp	95.00			J		10	Linear	0.00	2,500	Linear	0.00	0.800
105	Treat Impd Surface	Ag Sldg/Slurry	A11	1	Stuct & Car Adsorp	95.00			J		10	Linear	0.00	2.600	Linear	0.00	0.800
T02	Treat Impd Surface	Dilute Aq	A11	i	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	A11	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	A11	1	Stuct & Car Adsorp	95.00			J		10	linear	0.00	2,600	Linear	0.00	0,800
T02	Treat Imod Surface	2-Phase Ao/Oro	A11	1	Stuct & Car Adsorp	35.00			J		10	Linear	0.00	2,300	Linear	0.00	0.500
T02	Treat land Surface	Sub 2xx for 1xx	ALL	2	Stuct & Car Adsorp	95.00			3		10	Linear	0.00	2.900	Linear	0.00	1.200
105	Treat Impd Surface	Ag Sidg/Slurry	A11	2	Stuct & Car Adsorp	95.00			J		10	Linear	0.00	2,900	Linear	0.00	1,200
102	Treat Impd Surface	Dilute Aq	A11	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	A11	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	A11	2	Stuct & Car Adsorp	95.00			J		10	Linear	0.00	2,900	Linear	0.00	1,200
102	Treat Impd Surface	2-Phase Ao/Oro	A11	2	Stuct & Car Adsorp	95.00			j		10	Linear	0.00	2,500	Linear	0.00	0.700
T02	Funitives- Imp Load	Ag Sidg/Slurry	High	3					J								
102	Fugitives- Imp Load	Dilut Aq	High	3					J								
T02	Funitives- Twp Load	2-Phase Ag/Org	High	3					J								
T02	Funitives- Imp Load	Ora Liquid	High	3					J								
T02	Fugitives- Imp Load	Org Sidg/Slurry	High	3					J								
102	Trt Impd Surface	Sub 2xx for 1xx	A11	5	Syn Meubrane	85.00			Ĵ		10	Linear	0.00	0.460	Linear	0,00	0.060
102	Trt Impd Surface	Ag Sidg/Slurry	A11	5	Syn Nembrane	65.00			Ĵ		10	Linear	0.00	0.460	Linear	0.00	0.060
102	Trt lund Surface	Dilute Aq	A11	5	Syn Membrane	85.00			j		. 10	Linear	0.00	0.460	Linear	0.00	0.060
102	Trt Imod Surface	Sub 2xx for 4xx	A11	5	Syn Membrane	85.00			J		01	Linear	0.00	0.460	Linear	0.00	0,060
102	Trt Impd Surface	Sub 2xx for 5xx	A11	5	Syn Membrane	85.00			J		10	Linear	0.00	0,460	Linear	0,00	0,060
102	Int Impd Surface	2-Phase Ag/Org	A11	5	Syn Membrane	85.00			J		10	Linear	0.00	0.460	Linear	0.00	0.060
T03		VOC-cont Solid		1					E								
T03		Ag Sido/Siurry		1					E								
T03		Dilute Aq		1					E								
T03		Ore Liquid		1					E								
103		Org Side/Slurry		1					Ē								
103				1					E								
T03		2-Phase Aq/Org		i					E								
T04	Tank Surface	Sub 2xx for 1xx	A11	3	IFR, CAds, Vent to CI	84.50			H		10	Linear	0,00	0.220	Linear	0.00	0.10
T04	Tank Surface	Aq Sldg/Slurry	A11	3	IFR, CAds, Vent to CI	88.50			н		10	Linear	0.00	0, 220	Linear	0.00	0, 10

TABLE D-17 (continued)

TSDF			Vola-	Con-		Contr	ol efficie	ncy	Trans-		Ser-		Tot capi	al tal	Cost	Ann oper	ual ating
process code (1)	TSDF emission source (2)	Waste form (3)	tility class (4)	trol Index (5)	Emission control option (8)	Suppres- sion (7)	Emission control (8)	Removal (9)	fer code (10)	Lond- ing (11)	vice life (12)	Cost function (13)	<u>invest</u> (14)	bxQ (15)	func- tion (18)	(17)	t, s b x Q (18)
T04	Tank Surface	Dilute Aq	A11	3	IFR, CAds, Vent to CD	84,50			н		10	Linear	0.00	0.820	Linear	0.00	0.37
T04	Tank Surface	Org Liquid	A11	3	JFR, CAds, Vent to CD	91.75			H		10	Linear	0.00	0.360	Linear	0.00	0.25
T04	Tank Surface	Org Sldg/Slurry	A11	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	A11	3	IFR, Cads, Vent to CD	86.50			н		10	Linear	0.00	O. BOO	Linear	0.00	0.35
T04	Fugitives- Q Tank Ld	Ag Sldg/Slurry	High	5					H								
T04	Fugitives- Q Tank Ld	Dilut Ag	High	5					н								
T04	Funitives- 0 Tank Ld	Ore Side/Slurry	High	5					H								
T04	Fugitives- Q Tank Ld	Org Liquid	High	5					H								
T04	Fugitives- Q Tank Ld	Org Sidg/Siurry	High	5					H								
D79		VOC-cont Solid		1					F								
D79		Aq Sidg/Slurry		1					F								
D79		Dilute Aq		1					F								
D79		Org Liquid		3					F								
D79		Org Sldg/Slurry		1					F								
D79				1					f								
D79		2-Phase Aq/Org		1					F								
DBO	Landfill (Open)	Aq Sidg/Slurry	A1 1	1	Earth Cover	11.00					20	Linear	0.00	0.000	Linear	0.00	2.690
D80	Landfill (Open)	Sub 7xx for 3xx	A) 1	1	Earth Cover	11.00					20	Linear	0.00	0.000	Linear	0.00	2,630
DBO	Landfill (Open)	Sub 7xx for 4xx	A11	1	Earth Cover	11.00					50	Linear	0.00	0,000	Linear	0.00	2.690
DBO	Landfill (Open)	Sub 7xx for 5xx	A11	L	Earth Cover	11.00					20	Linear	0.00	0.000	Linear	0.00	2.690
D80	Landfill (Open)	2-Phase Aq/Org	A11	1	Earth Cover	11.00					20	Linear	0,00	0.000	Linear	0.00	2,690
080	Landfill (Open)	VDC-cont Solid	A11	1	Earth Cover	11.00					0	Linear	0.00	0,000	Linear	0.00	2.690
D80	Landfill (Closed)	VOC-cont Solid	A11	3	HD Cover 30 mil	0.00					30	Linear	0.00	0.760	Linear	0.00	0.030
D80	Landfill (Closed)	Aq Sldg/Slurry	A11	3	HD Cover 30 mil	99.70					30	Linear	0.00	0.750	Linear	0.00	0.030
DBO	Landfill (Closed)	Sub 7xx for 3xx	A11	3	HD Cover 30 wil	49,30					30	Linear	0.00	0,760	Linear	0,00	0.030
D80	Landfill (Closed)	Sub 7xx for 4xx	A11	3	HD Cover 30 ∎i1	49.30					30	Linear	0.00	0,760	Linear	0.00	0.030
DB O	Landfill (Closed)	Sub 7xx for 5xx	A11	3	HD Cover 30 mil	49, 30					30	Linear	0.00	0,750	Linear	0.00	0.030
D80	Landfill (Closed)	2-Phase Aq/Org	A11	3	HD Cover 30 mil	49.30					30	Linear	0.00	0.760	Linear	0.00	0.030
080	Landfill (Closed)	VDC-cont Solid	A11	4	HD Cover 100 mil	0.00					30	Linear	0.00	1.960	Linear	0.00	0.080
D80	Landfill (Closed)	Aq Sldg/Slurry	A11	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	A11	4	HD Cover 100 #i)	84.80					30	Linear	0.00	1.960	Linear	0.00	0, 080
D80	Landfill (Closed)	Sub 7xx for 4xx	A]]	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	A11	4	.HD Cover 100 mil	84.80					30	Linear	0.00	1.950	Linear	0.00	0.080
D80	Landfill (Closed)	2-Phase Aq/Org	A1 1	4	HD Eover 100 mil	84.60					30	Linear	0,00	1.960	Linear	0.00	0,080

TABLE D-17 (continued)

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TSDF	TSDF		Volm- tility	Con- trol	Emission	<u>Cont</u>	col efficie Emission	incy	Trens- fer	Lond-	Ser- vice	Cost	To cap inves	tel itel tment, 1	Cost func-	Ann oper <u>co</u> s	uəl əting it, \$
code (1)	emission source (2)	Waste form (3)	class (4)	index (5)	control option (6)	sion (7)	control (8)	Removal (9)	code (10)	ing (11)	life (12)	function (13)	(14)	ЬхQ (15)	tion (16)	1 (17)	ЬхQ (18)
D83	Fugitives- I∎p Load	Aq Sldg/Slurry		1					к								
D83	Fugitives- Imp Load	Sub 2xx for 4xx		1					К								
DB3	Fugitives- Imp Load	2-Phase Aq/Org		1					К								
DB3	Fugitives- Imp Load	Sub 2xx for 4xx		1					к								
D83	Fugitives- Imp Load	Sub 2xx for 5xx		1					К								
FXP	Fixation Pit	Aq Sldg/Slurry	A11	3			95,00				20	Linear	0.00	12.030	Linear	0.00	3.720
FXP	Fixation Pit	Sub 7xx for 3xx	A11	3			95,00				20	Linear	0.00	12.030	Linear	0.00	3.720
FXP	Fixation Pit	Sub 7xx for 4xx	A11	3			95,00				20	Linear	0.00	12.030	Linear	0.00	3,720
FXP	Fixation Pit	Sub 7xx for 5xx	A11	3			95, 00				20	Linear	0.00	12,030	Linear	0.00	3, 720
FXP	Fixation Pit	2-Phase Aq/Org	A11	3			95.00				20	Linear	0,00	12.030	Linear	0,00	3.720
FXP	Fixation Pit	VOC-cont Solid	A]]	3			95.00				20	Linear	0.00	12, 030	Linear	0.00	3.720

TABLE D 17 (continued)

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

^bThe 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 = V0 removal efficiency.
 9 = Letter indicator for engaging fugitive controls; refers to Table D-19, column 1, THL process indicator.
 11 = Letter indicator for engaging loading controls; refers to Table D-19, column 1, THL process indicator.

- 12 = Service life of control equipment (yr).
 13 = Cost function description, for capital investment.
 14 = Fixed control cost for capital investment.
- 15 = Throughput multiplier for capital investment.
- 16 = Cost function description for annual operating cost.
- 17 = Fixed annual operating cost.
- 18 = Throughput multiplier for annual operating cost.

TSDF			Vola-	Con-		Contr	ol officie	ancy	Trans-	Ser-		T. CB	otal pital		Апа	iua! ating
process	Treatment	Waste form	tility	trol index	Emission control option	Suppres-	Emission	Removal	fer	vice	Cost	inves	tment, \$	Cost		iost
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
LTA	Liq Inject Incin	Organic Liquid	Å11	I	Liq Inject Incin			99.9 9	E	10	Linear	0.00	152, 740		0.00	137.900
LTA	Fluid Bed Incin	Aq Sidg/Siur	A11	5	Fluid Bed Incin			39. 99	E	10	Linear	0,00	152,740	Linear	0.00	137.300
LTA	Rotary Kilm Incim	VD Cont Solids	A11	3	Rotary Kiln Incin			99. 99	E	10	Linear	0,00	152.740		0.00	137.900
LTA	Fluid Bed Incin	Org Sidg/Siur	A1 1	4	Hearth Incin			93.93	E	10	Linear	0,00	152.740		0.00	137.900
INC	Liq Inject Incin	Organic Liquid	A)]	1	Lig Inject Incin			99.99	E	10	Linear	0.00	80.660	Linear	0.00	0.000
INC	Liq Inject Incin	Organic Liquid	A11	1	Lig Inject Incin			93.99	Ε	10	Linear	0.00	188.890	Linear	0.00	30.880
INC	Rotary Kiln Incin	Org Sldg/Slur	A11	1	Rotary Kiln Incin			99, 99	E	10	Linear	0.00	12.280	Linear	0.00	1.230
INC	Rotary Kiln Incin	Org Sidg/Siur	A11	i	Rotary Kiln Incin			93.99	E	10	Linear	0.00	467.000	Linear	0.00	70.100
INC	Rotary Kiln Incin	VO Cont Solids	A11	i	Rotary Kiln Incin			99, 99	E	10	Linear	0.00	4.460	Linear	0.00	0.447
INC	Rotary Kiln Incin	VO Cont Solids	A11	1	Rotary Kiln Incin			39.99	E	10	Linear	0.00	284.000	Linear	0,00	63.660
VOC	Air Stripper (99%)	Dilute Aqueous	High	1	Air Stripper (99%)			99.00	L	15	Linear	0.00	1.664	Linear	0.00	0.179
VOC	Air Stripper (99%)	Dilute Aquecus	Medium	1	Air Stripper (39%)			13.70	L	15	Linear	0.00	0.387	Linear	0.00	0.589
VOC	Air Stripper (39%)	Dilute Aqueous	Low	1	Air Stripper (99≭)			1.10	L	15	Linear	0,00	1,563	Linear	0.00	0.306
VOC	Air Stripper (99%)	Dilute Aqueous	A]]	1	Catalytic Incin			98,00	L	15	Linear	0.00	0	Linear	0,00	0
VOC	Air Stripper (39%)	Dilute Aqueous	A11	1	No Control			0.00	L							
VOC	Steam Stripper (99%)	Dilute Aqueous	Hiah	2	Steam Stripper (99%)		98,40	99, 99	ι	15	Linear	0.00	1.519	Linear	0.00	0.256
VOC	Steam Stripper (99%)	Dilute Aqueous	Medium	2	Steam Stripper (99%)		99.96	94.50	ι	15	Linear	0,00	3. 547	Linear	0.00	3.430
VOC	Steam Stripper (99%)	Dilute Aquecus	Low	2	Steam Stripper (99%)		99, 99	16, 45	-u	15	Linear	0.00	0.013	Linear	0.00	0.123
VDC	Steam Stripper (99%)	Dilute Aqueous	A11	2	Vent to CD			95.00	L	15	Linear	0.00	0.000	Linear	0.00	0.122
VDC	Steam Stripper (99%)	Dilute Aqueous	A11	2	No Control			0.00	۶L							
VDC	Batch Distill (99%)	Ornanic Liquid	Hish	2	Batch Distill (99%)		98, 40	99.00	ī	15	Linear	0.00	9.068	Linear	0.00	1.180
VDC	Batch Distill (99%)	Ornanic Liguid	Medium	2	Batch Distill (99%)		99.96	18,00	ī	15	Linear	0.00	5.634	Linear	0.00	13.820
VDC	Batch Distill (99%)	Ormanic Liquid	1.04	2	Batch Distill (99%)		99.99	6.00	ī	15	Linear	0.00	3,957	Linear	0.00	-37, 980
VBC	Batch Distill (99%)	Ornanic Liquid	A11	2	Vent to CD			35.00	÷.	15			0.0728	Linear	0,00	0.386
VDC	Batch Distill (991)	Ornanic Liquid	A11	2	No Control			0.00	Ē							
VOC	Rot Kiln Inc (99, 99%)	Orn Sidn/Siur	Hinh	2	Rotary Kiln Incin		100.00	99, 99	ī	10	Linear	0.00	12.280	Linear	0.00	1.230
VIIC	Rot Kiln Inc (99, 99%)	Orn Sida/Siur	Medium	2	Rotary Kiln Incin		100.00	93, 99	Ē	10	Linear	0,00	467.000	linear	0.00	70,100
VIIC	Rot Kiln Inc (99, 99%)	Org Sidg/Siar	Low	2	Rotary Kiln Incin		100.00	99,99	ī	10	Linear	0.00	0.000	Linear	0.00	0.000
VAC	Rot Kiln Inc (99, 99%)	Dra Sida/Siur	A11	2	Combustion			0.00	Ē	10	Linear	0.00	0.000	linear	0,00	0.000
VIIC	Rot Kiln loc (93, 934)	Orn Sidn/Siur	Δ11	2	No Control			0.00	1	•••				21/120/		
VIIC	Thin Film Evan (99%)	Do Sidn/Sive	Hinh	2	Thin Film Evan (99%)		38.40	99.78	ĩ	15	linear	0.00	18,735	linear	0.00	4.340
vnr	Thir Film Evan (991)	On Sida/Sium	Nedium	2	Thin Film Evan (99%)		99.96	65, 90	1	15	linear	0.00	62.653	linear	0.00	15,850
var	Thin Film Evan (994)	On Sidn/Sium	Low	2	Thin Film Evan (994)		99,99	20.69	ĩ	15	linear	0.00	0.821	linear	0,00	-3.640
UNC	This File Even (204)	An Cida/Sium	Δ11	2	Vent to CB			95 00	ĩ	35	linear	0,00	2.548	Lincor	0.00	0.510
VAC	This Sile Even (004)	ng blog/blue	011	2	No Control			0.00	-	10	CTHEOL.		2.270	Linear	0.00	01010
400	min cita cvap (35A)	ավ թյոնչելու	HII	c	NO CONTROL			0.00	·							

TABLE D-10. ORGANIC REMOVAL AND INCINERATION CONTROL COST FILE USED BY THE SOURCE ASSESSMENT MODEL®, b

TABLE D-18 (co	nt.	inued)	
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												Т	otal		Ani	nual
TSDF			Vola-	Con-		Contr	ol efficie	ncy	Trens-	Ser-		Ca	pitel		oper	rating
ргосеза	Trestment		tility	trol	Emission	Suppres-	Emission		fer	vìce	Cost	inves	tment, \$	Cost		cost
code	device	Waste form	class	index	control option	sion	control	Removal	code	life	function		Ь×Q	function		Ь×Q
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)

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

- ^bThe 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 = YO removal efficiency.
 9 = YO removal efficiency.
 10 = Letter indicator for engaging fugitive control; 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.

THL			Vola- tilitv	Con- trol	Emission control	Control	Ser-	Cast	Total o invest	apital ment, S	Cost	Ann operat	ual ing cost
indicator	Emission source	Waste form	class	Index	option	(suppression)	life	function	•	b × Q	function	•	b x Q
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
A	Drum Loading	VOC-Cont Solid	A11	1	Submerged Loading	65.00	15	Linear	0.00	0.43000	Linear	0.00	0.03000
A	Drum Loading	Aq Sldq/Slur	A11	1	Submerged Loading	65.00	15	Linear	0.00	0,70000	Linear	0.00	0.04000
A	Drum Loading	Dil Aqueous	A11	1	Submerged Loading	65.00	15	Linear	0,00	0,87000	Linear	0.00	0.04000
A	Drum Loading	Org Liquid	A11	1	Submerged Loading	65,00	15	Linear	0.00	0.89000	Linear	0.00	0.05000
A	Drum Loading	Org Sldg/Slurry	A11	1	Submerged Loading	65.00	15	Linear	0.00	0.64000	Linear	0.00	0.03000
A	Drum Loading	2-Phase Aq/Org	A11	1	Subwerged Loading	65,00	15	Linear	0.00	0.83000	Linear	0.00	0.05000
B	Truck Loading	Aq Sidg/Slur	A1 1	1	Submerged Loading	65.00	15	Linear	0,00	0.75000	Linear	0,00	0.04000
B	Truck Loading	Dil Aqueous	A]]	1	 Submerged Loading 	65.00	15	Linear	0.00	0.92000	Linear	0.00	0.05000
8	Truck Loading	Org Liquid	A1 1	1	Submerged Loading	65.00	15	Linear	0.00	0.94000	Linear	0.00	0.05000
B	Truck Loading	Org Sidg/Slurry	A11	1	Submerged Loading	65.00	15	Linear	0.00	0.78000	Linear	0.00	0.04000
B	Truck Loading	2-Phase Aq/Org	A))	1	Submerged Loading	65.00	15	Linear	0.00	0.79000	Linear	0.00	0.04000
C	Fugitives- Drum Loading	Aq Sldg/Slurry	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	19, 56250	Linear	918.00	6.22690
C	Fugitives- Drum Loading	Dil Aqueous	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	19.56250	Linear	918.00	6.22690
С	Fugitives- Drum Loading	Org liquid	High	i	Monthly Inspt/Repair	70,29	10	Linear	6318.00	19, 56250	Linear	918.00	6,22690
С	Fugitives- Drum Loading	Org Sldg/Slurry	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	19.56250	Linear	918.00	6.22690
C	Fugitives- Drum Loading	2-Phase Aq/Org	High	1	'Monthly Inspt/Repair	70.29	10	Linear	6318.00	19.56250	Linear	918.00	6.22690
D	Fugitives- Sto Tank Loading	Aq Sldg/Slur	High	i	Monthly Inspt/Repair	70, 29	10	Linear	631B.00	3.86580	Linear	918.00	1.23050
D	Fugitives- Sto Tank Loading	Dil Aqueous	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	3.86580	Linear	918,00	1.23050
D	Fugitives- Sto Tank Loading	Drg Liquid	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	3.86580	Linear	918.00	1.23050
D	Fugitives- Sto Tank Loading	Org Sidg/Slurry	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	3,86580	Linear	918.00	1.23050
D	Fugitives- Sto Tank Loading	2-Phase Aq/Org	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	3.86580	Linear	918.00	1.23050
E	Fugitives- Incin Load (TO2)	Aq Sldg/Slur	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.56580	Linear	918.00	0.18100
E	Fugitives- Incin Load(TO2)	Dil Aqueous	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.56580	Linear	918.00	0.18100
E	Fugitives- Incin Load(TO2)	'Drg Liquid	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318,00	0.56580	Linear	918.00	0.18100
E	Fugitives- Incin Load(TO2)	Org Sidg/Slurry	High	1	Monthly Inspt/Repair	70, 29	10	Linear	6318.00	0,56580	Linear	918.00	0. 18100
E	Fugitives- Incin Load(TO2)	2-Phase Aq/Org	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.56580	Linear	918.00	0,18100
F	Fugitives-Inj Well Load(TO2)	Aq Sldg/Slur	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.11410	Linear	918.00	0.03630
F	Fugitives-Inj We)) Load(TD2)	Dil Aqueous	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.11410	Linear	918.00	0.03630
F	Fugitives-Inj Well Load(TD2)	Org Liquid	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.11410	Linear	918.00	0.0363(
F	Fugitives-Inj Hell Load(TO2)	Org Sldg/Slurry	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0,11410	Linear	918,00	0.03630
F	Fugitives-Inj Well Load(TD2)	2-Phase Ag/Drg	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.11410	Linear	918.00	0.03630
6	Fugitives- Aertd Treat Tank Loading	Aq Sldg/Slur	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01650	Linear	918,00	0.00520
6	Fugitives- Aertd Treat Tank Loading	Dil Aqueous	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01650	Linear	918.00	0.00520
G	Fugitives- Aertd Treat Tank Loading	2-Phase Ag/Orp	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318,00	0.01650	Linear	918,00	0.00526

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

THL			Vola- tility	Con-	Emission centrol	Control	Ser-	Cost	Total ca investm	pitel mont, S	Cost	Anno operat	usl ing cost
indicator (1)	Emission source (2)	Waste form (3)	class (4)	index (5)	option (6)	(suppression) (7)	life (8)	function (9)	• (10)	ЬхQ (11)	function (12)	(13)	ь х Q (14)
6	Funitives- Aertd Treat Tank Loading	Orn Liouid	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01650	Linear	918.00	0.00520
G	Funitives- Aertd Treat Tank Loading	Orn Sidn/Simry	High	i	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.01650	Linear	918.00	0.00520
H	Funitives- Dect Treat Tank Loading	An Sida/Siur	High	1	Monthly Inspt/Repair	70, 29	10	Linear	6318.00	0.08380	Linear	918.00	0.02670
н	Funitives- Oset Treat Tank Loading	Dil Aqueous	High	1	Monthly Inspt/Repair	70.23	10	Linear	6318.00	0.08380	Linear	318.00	0.02670
н	Funitives- Osct Treat Tank Loading	2-Phase An/Dro	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.08380	Linear	918.00	0.02670
н	Funitives- Osct Treat Tank Loading	Orn Liquid	High	i	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.08380	Linear	918.00	0.02670
н	Funitives- Osct Treat Tank Loading	Drn Sido/Siurry	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.08380	Linear	918.00	0.02670
ï	Funitives- Storage Imp Loading	An Sida/Siur	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.74040	Linear	918.00	0.23570
ī	Funitives- Storage Imp Loading	Dil Apueous	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318,00	0.74040	Linear	918.00	0.23570
i	Funitives- Storage Imp Loading	2-Phase Ao/Org	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.74040	Linear	918.00	0.23570
ī	Funitives- Storage Imp Loading	Ora Liquid	High	1	Monthly Inspt/Repair	70.23	10	Linear	6318,00	0.74040	Linear	918.00	0.23570
ī	Fugitives- Storage Imp Loading	Ora Sldø/Slurry	Hiph	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.74040	Linear	918.00	0.23570
J	Funitives- Treat Imp Loading	Ao Sida/Siur	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.01140	Linear	918,00	0.00360
J	Fugitives- Treat Imp Loading	Dil Aqueous	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318,00	0.01140	Linear	918.00	0.00360
J	Funitives- Treat Imp Loading	2-Phase Ag/Org	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.01140	Linear	918.00	0.00360
J	Funitives- Treat Imp Loading	Ora Liquid	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.01140	Linear	918.00	0.00360
J	Funitives- Treat Imp Loading	Ora 51da/Slurry	High	1	Monthly Inspt/Repair	70, 29	10	Linear	6318.00	0.01140	Linear	918.00	0.00360
ĸ	Fugitives- Disp Imp Loading	Ac Side/Siur	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.13700	Linear	918.00	0.04360
ĸ	Funitives- Disp Imp Loading	Dil Aqueous	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.13700	Linear	918.00	0.04360
ĸ	Funitives-Disp Imp Loading	2-Phase Ag/Org	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.13700	Linear	918.00	0.04360
ĸ	Fugitives- Disp Imp Loading	Org Liquid	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.13700	Linear	918.00	0.04360
к	Funitives- Disp Imp Loading	Drn Sldg/Slurry	- High	1	Nonthly Inspt/Repair	70,29	10	Linear	6318.00	0,13700	Linear	918.00	0.04360
ï	Funitives- Incinerator	VOC-Cont Solid	High	1	Monthly Inspt/Repair	70,29	10	Linear	6318.00	0.29160	Linear	918.00	0.03280
ĩ	Funitives- TFE	An Sida/Siurry	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.73410	Linear	918,00	0.23370
ĩ	Funitives- Air Stripper	Dilute Aqueous	High	1	Monthly Inspt/Repair	70.23	10	Linear	6318,00	0,03970	Linear	918.00	0.01260
L	Funitives- Batch distillation	Ora Liquid	High	1	Monthly Inspt/Repair	70, 29	10	Linear	6318.00	1.24770	Linear	918.00	0.39720
ĩ	Funitives- Incinerator	Org Sidg/Slurry	High	1	Monthly Inspt/Repair	70.29	10	Linear	6318.00	0.80180	Linear	918.00	0,25520
i	Funitives- Stream stripper	2-Phase Ag/Org	High	1	Monthly Inspt/Repair	70.29	10	Linear	631B.00	0.17700	Linear	918.00	0.05630

TABLE D-19 (continued)

TABLE D-19 (continued)

THL process			Vois- tility	Con- trol	Emission control	Control officiency	Ser- vice	Cost	Total c invest	epital ment, \$	Cost	Anni operat	ual ing cost
indicator	Emission source	Waste form	class	index	option	(suppression)	life	function	a	ЬхQ	function	(13)	ЬжQ
(1)	(2)	(3)	(4)	(5)	(8)	(7)	(8)	(9)	(10)	(11)	(12)		(14)

^BThis table contains all cost-related data necessary to estimate control cost impacts with the Source Assessment Model.

^bThe 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.

- a mission control definition.
 Suppression control efficiency.
 B = 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.

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. It should be noted that, in estimating nationwide costs, a cost for waste storage for organics removal and incineration processes is included only for those TSDF that do not have existing drum or tank storage capable of holding the waste.

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 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

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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 levels (VO concentration cutoffs) 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 cutoff. The regulated wastes that are identified for control are used in

the SAM to determine the nationwide impacts of the given VO cutoff 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 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

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	Waste matrix					
Volatility class	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	0c	0c			

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

NA = Not applicable.

^aThis 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.

^bAssumes that the test method will remove all of the highly volatile gases from the waste.

^CAssumes that because of the very low vapor pressure for this category (<1.33 x 10^{-4} kPa) the test method will remove very little from the waste.

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

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

^aThis 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.

^bThe 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 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.

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 facility incidences are summed to give the nationwide TSDF incidence value.

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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 facility (e.g., total annual emissions for each TSDF), by management process (e.g., nationwide emissions for all open storage impoundments), and by source (e.g., nationwide or facility emissions from process losses, spills, or transfer and handling). For each facility, the emission and cost data are available for each waste stream, 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 better expressed in terms of overall facility 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

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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 singledose, 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 (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 factors, 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 guantal 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 these facts, 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 presently 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 by 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 Factors

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. Most of these unit risk estimates have either been verified by the Agency's Carcinogen Risk Assessment Verification Enterprise (CRAVE) or are under review by CRAVE. As shown in Table E-1, these factors range in value from 4.7 x 10^{-7} (μ g/m³)⁻¹ for methylene chloride to 3.3 x 10^{-5} (pg/m³)⁻¹ for dioxin.

Emissions have been estimated from TSDF for some 70 organic compounds that are either known or suspected carcinogens. Risk factors are available for many, but not all, of these species.

E.1.2 Composite Unit Risk Factor

To estimate the cancer potency of TSDF air emissions, a composite unit risk factor approach was adopted to address the problem of dealing with the large number of toxic chemicals that are present at TSDF. Using a composite factor rather than individual unit risk factors simplifies the risk assessment so that calculations do not need to be performed for each chemical emitted. The composite risk factor 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 risk factors 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 factor for that compound. The emission-weighted arithmetic average is computed as follows:

		Unit risk estimate.	
	Constituent	$(\mu g/m^3) - 1$	Basis ^a
1.	acetaldehyde (75-07-0)	2.2x10-6	CRAVE verified (class B2)
2.	acrylamide (79-06-1)	1.1×10-3	CAG UCR (class B2)
3.	acrylonitrile (107-13-1)	6.8×10 ⁻⁵	CRAVE verified UCR (class B1)
4.	aldrin (309-00-2)	4.9×10-3	CRAVE verified UCR (class B2)
5.	aniline (62-53-3)	7.4x10-6	CAG UCR (class C)
6.	arsenic (7440-38-2)	4.3x10-3	CRAVE verified (class A)
7.	benz(a)anthracene (56-55-3)	8.9x10-4	CAG UCR (class B2)
8.	benzene (71-43-2)	8.3x10-6	CRAVE verified (class A)
9.	benzidine (92-87-5)	6.7x10-2	CRAVE verified UCR (class A)
10.	benzo(a)pyrene (50 - 32-8)	1.7x10-3	CAG UCR (class B2)
11.	beryllium (7440-41-7)	2.4x10-3	CAG UCR (class B2)
12.	bis(chloroethyl) ether (111–44–4)	3.3×10-4	CRAVE verified UCR (class B2)
13.	bis(chloromethyl) ether (542-88-1)	2.7x10-3	CAG UCR (class A)
14.	1,3-butadiene (106-99-0)	2.8x10-4	CRAVE verified UCR (class B2)
15.	cadmium (7440-43-9)	1.8x10-3	CRAVE verified UCR (class B1)

TABLE E-1. TSDF CARCINOGEN LIST

		Unit risk estimate,	
	Constituent	(µg/m ³) ⁻¹	Basis ^a
16.	carbon tetra- chloride (56-23-5)	1.5×10-5	CRAVE verified UCR (class B2)
17.	chlordane (12789-03-6)	3.7×10-4	CRAVE verified UCR (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 UCR (class C)
20.	chloromethyl methyl ether (107-30-2)	2.7×10-3	CAG UCR (class A)
21.	chromium VI (7440-47-3)	1.2×10-2	CRAVE verified UCR (class A)
22.	DDT (50-29-3)	3.0×10-4	CAG UCR (class B2)
23.	dibenz(a,h) anthracene (53-70-3)	1.4x10-2	CAG UCR (class B2)
24.	1,2-dibromo-3- chloropropane (96-12-8)	6.3×10-3	CAG UCR (class B2)
25.	1,2-dichloroethane (107-06-2)	2.6×10 ⁻⁵	CRAVE verified UCR (class B2)
26.	1,1-dichloro- ethylene (75-35-4)	5.0×10 ⁻⁵	CRAVE verified UCR (class C)
27.	dieldrin (60-57-1)	4.6×10-3	CRAVE verified UCR (class B2)
28.	2,4-dinitrotoluene (121-14-2)	8.8×10 ⁻⁵	CAG UCR (class B2)

TABLE E-1 (continued)

	Constituent	Unit risk estimate (µg/m3)-1	Basisa
29.	1,4-dioxane (123-91-1)	1.4x10-6	CAG UCR (class B2)
30.	1,2-diphenylhydrazine (122-66-7)	2.2×10 ⁻⁴	CRAVE verified (class B2)
31.	epichlorohydrin (106-89-8)	1.2x10-6	CRAVE verified UCR (class B2)
32.	ethylene dibromide (106-93-4)	2.2×10-4	CRAVE verified UCR (class B2)
33.	ethylene oxide (75-21-8)	1.0×10-4	CAG UCR (class B1-B2)
34.	formaldehyde (50-00-0)	1.3x10-5	CAG UCR (class B1)
35.	gasoline (8006-61-9)	6.6x10 ⁻⁷	CAG UCR (class B2)
36.	heptachlor (76-44-8)	1.3x10 ⁻³	CRAVE verified UCR (class B2)
37.	heptachlor epoxide (1024-57-3)	2.6x10-3	CRAVE verified UCR (class B2)
38.	hexachlorobenzene (118–74–1)	4.9×10-4	CAG UCR (class B2)
39.	hexachlorobutadiene (87-68-3)	2.2x10 ⁻⁵	CRAVE verified UCR (class C)
40.	hexachlorocyclohexane (no CAS #)	5.4×10-4	CRAVE verified UCR (class B2)
41.	alpha-hexachloro- cyclohexane (319-84-6)	1.8x10-3	CRAVE verified UCR (class B2)
42.	beta-hexachloro- cyclohexane (319-85-7)	5.3x10-4	CRAVE verified UCR (class B2)

TABLE E-1 (continued)

<u> </u>		Unit risk estimate,	
	Constituent	(µg/m ³)-1	Basis ^a
43.	gamma-hexachloro- cyclohexane (lindane)(58-89-9)	3.8×10-4	CRAVE verified UCR (class C)
44.	hexachlorodibenzo- p-dioxin,1:2 mixture (57653-85-7 or 19408-74-3)	1.3×10-6	CRAVE verified UCR (class B2)
45.	hexachloroethane (67-72-1)	4.0x10-6	CRAVE verified UCR (class C)
46.	hydrazine (302-01-2)	2.9x10-3	CAG UCR (class B2)
47.	3-methylcholanthrene (56-49-5)	2.7×10-3	CAG UCR (class B2)
48.	4,4'-methylene-bis (2-chloroaniline) (101-14-4)	4.7×10-5	CAG UCR (class B2)
49.	methylene chloride (75-09-2)	4.7×10-7	CAG UCR UCR (class B2)
50.	methyl hydrazine (60-34-4)	3.1×10-4	ECAO UCR (class B2)
51.	nickel refinery dust (7440-02-0)	2.4x10-4	CRAVE verified UCR (class A)
52.	nickel subsulfide (12035-72-2)	4.8×10-4	CRAVE verified UCR (class B2)
53.	2-nitropropane (79-46-9)	2.7x10-3	CAG UCR (class B2)
54.	n-nitrosodi-n- butylamine (924-16-3)	1.6×10-3	CRAVE verified UCR (class B2)
55.	n-nitroso- diethylamine (55-18-5)	4.3x10-2	CRAVE verified UCR (class B2)

TABLE E-1 (continued)

	Constituent	Unit risk estimate, (ug/m3)-1	Racicd
56.	n-nitroso- dimethylamine (62-75-9)	1.4×10-2	CRAVE verified UCR (class B2)
57.	n-nitroso-n- methylurea (684-93-5)	8.6×10-2	CAG UCR (class B2)
58.	n-nitroso- pyrrolidine (930-55-2)	6.1×10-4	CRAVE verified UCR (class B2)
59.	pentachloronitro- benzene (82-68-8)	7.3x10-5	CAG UCR (class C)
60.	polychlorinated biphenyls (1336-36-3)	1.2×10-3	CAG UCR (class B2)
61.	pronamide (23950-58-5)	4.6×10-6	CAG UCR (class C)
62.	reserpine (50-55-5)	3.0×10-3	CAG UCR (class B2)
63.	2,3,7,8-tetrachloro- dibenzo-p-dioxin (1746-01-6)	3.3x10-5 (pg/m ³)-1	CAG UCR (class B2)
64.	1,1,2,2-tetra- chloroethane (79-34-5)	5.8x10-5	CRAVE verified UCR (class C)
65.	tetrachloroethylene (127-18-4)	5.8×10 ⁻⁷	CAG UCR UCR (class B2)
66.	thiourea (62-56-6)	5.5x10-4	CAG UCR (class B2)
67.	toxaphene (8001-35-2)	3.2x10-3	CRAVE verified UCR (class B2)

TABLE E-1 (continued)

	Constituent	Unit risk estimate (µg/m ³)-1	Basisa
68.	1,1,2-trichloro- ethane (79-00-5)	1.6x10-5	CRAVE verified UCR (class C)
69.	trichloroethylene (79-01-6)	1.7×10-6	CAG UCR (class B2)
70.	2,4,6-trichloro- phenol (88-06-2)	5.7x10-6	CRAVE verified UCR (class B2)
71.	vinyl chloride (75-01-4)	4.1×10-6	CAG UCR (class A)

TABLE E-1 (continued)

() = Chemical Abstracts Service (CAS) Number.

^aUnit cancer risk (UCR) estimates 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 and exposure limits are subject to change.

$$\overline{RF}_{W} = \frac{\sum_{i=1}^{N} (RF_{i} \cdot ER_{i})}{ER_{i}} , \qquad (E-1)$$

where

 \overline{RF}_{W} = weighted average risk factor RF_{i} = risk factor for compound i ER_{i} = emission rate.

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

Table E-2 shows the compounds included in the development of the composite risk factor, total nationwide emissions by compound, the unit risk factor by compound, and the weighted-average unit risk estimate. When dioxin was included in the calculation, a composite unit risk estimate of $8.6 \times 10^{-6} \ (\mu g/m^3)^{-1}$ was determined. Without dioxin a unit risk estimate of $3.0 \times 10^{-6} \ (\mu g/m^3)^{-1}$ was calculated.

Some difficulties arise in using an emission-weighted average for the composite unit risk factor. As noted earlier, unit risk factors 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; i.e., to present the composite risk factor and associated cancer risks separately for Class A compounds, Class B compounds, and Class C compounds. However, since only about 4 percent of the weighted composite risk factor is attributed to Class A compounds and about 6 percent for Class C, EPA elected to present the risk associated with all three classes combined.

Chemical	10R ^a uncontrolled		URF x emissions for chemical
name (carcinogen)	emissions, Mg/yr	URF	Total TSDF emissions
1.1-dichloroethylene	1.093	5.0 × 10 ⁻⁵	3.0×10^{-8}
1,2-diphenyl hydrazine	1	2.2×10^{-4}	8.8×10^{-11}
1,2-dibromoethane	Ø	2.2×10^{-4}	Ø
1,2-dibromo-3-chloropropane	2	5.0 x 10 ⁻³	4.6 × 10 ⁻⁹
1,2-dichloroethane	23,101	2.6 x 10^{-5}	3.3×10^{-7}
1,4-dioxane	270	1.0×10^{-6}	1.5×10^{-10}
2-nitropropane	8	3.0×10^{-3}	1.4×10^{-8}
acetaldehyde	6,214	2.2 × 10 ^{−6}	7.4×10^{-9}
acetonitrile	469.100	_	_
acrylamide	74	1.0×10^{-3}	4.0×10^{-8}
acrylonitrile	17,770	6.8×10^{-5}	6.6×10^{-7}
aldrin	34	4.9 x 10 ⁻³	8.9 × 10 ⁻⁸
allyl chloride	248.600	_	•
aniline	5,38Ø	1.0 x 10 ⁻⁵	2.9×10^{-8}
benzene	6154.000	8.0 x 10 ⁻⁶	2.7×10^{-8}
benzotrichloride	21.653	•	•
benzo(a)pyrene	2	1.7×10^{-3}	1.4×10^{-9}
benzo(b)fluoranthene	1.219		
benzylchloride	289.800	4	19
benz(a)anthracene	Ø.23Ø	8.9×10^{-4}	1.1×10^{-10}
bis(chloromethyl)ether	374		
bis(2-chloroethyl)ether	Ø	3.3×10^{-4}	Ø
bis(2-ethylhexyl)phthalate	338.062		
bromo-2-chloroethane	10.310		•
butadiene	115	2.8 × 10 ⁻⁴	1.8×10^{-8}
carbazole	46.760	_	-
carbon tetrachloride	16,920	1.5×10^{-5}	1.4×10^{-7}
chlordane	8	3.7×10^{-4}	1.6×10^{-9}
chloroform	4,588	2.3×10^{-5}	5.7×10^{-8}
chloromethyl methyl ether	Ø	2.7 × 10 ⁻³	Ø
chloronitrobenzene	2508.980		
chrysene	0.316		
creosote	17.110		
DDT	27	3.0×10^{-4}	4.5×10^{-9}
dibenz(a,h)anthracene	0.053	1.4 × 10 ⁻²	4.0×10^{-10}
dichlorobenzene(1,4) (p)	0.085		
dichloropropene	30.540		
dimethoxy benzidine, (3,3')	0.000		
dimethyl phenol	21.310		
dimethyl sulfate	Ø.192	o o , , , , , , , , , , , , , , , , , ,	· · · · · · · · · · · · · · · · · · ·
dinitrotoluene	250.000	8.8×10^{-5}	1.2×10^{-6}
epichlorohydrin	1,595	1.2×10^{-5}	1.0×10^{-9}
ethyl acrylate	28.920		
ethyl carbamate	12.180		

Chemical	LDR uncontrolled		<u>URF x emissions for chemical</u>
name (carcinogen)	emissions, mg/yr	URF	Total TSDF emissions
ethylene dibromide	10	2.2×10^{-4}	1.2×10^{-9}
ethylene imine (azaridine)	51640.000		
ethylene oxide	0.000	1.0×10^{-4}	0.000
formaldehyde	2,645	1.3×10^{-5}	1.9×10^{-8}
gasoline	2,742	6.6×10^{-7}	9.8×10^{-10}
heptachlor	1	1.3×10^{-3}	8.6×10^{-10}
hexach lorobenzene	158	4.9×10^{-4}	4.2×10^{-8}
hexachlorobutadiene	45780.000	2.2×10^{-5}	5.4×10^{-7}
hexachloroethane	1,553	4.0×10^{-6}	3.4×10^{-9}
hydrazine	238	2.9 × 10 ⁻³	3.8×10^{-7}
indeno(123-cd)pyrene	Ø.Ø33		
lead acetate	1.901		
lead subacetate	Ø.ØØØ_		
lindane	9.5 × 10 ⁻⁵	3.8×10^{-4}	2.0×10^{-14}
methyl chloride	58	-	_
methyl cholanthrene (3)	5	3.0 × 10 ⁻³	8.6 × 10 ⁻⁹
methyl hydrazine	8		
methyl iodide	0.000	_	1
methylene chloride	16,676	4.7 × 10 ⁻⁷	4.3 x 10 ⁻⁹
nitrobenzene	5438.900		
nitro-o-toluidine	0.000		
n-nitrosopyrrolidine	0.000	6.1×10^{-4}	Ø
n-nitroso-n-methylurea	0.000	8.6 × 10 ^{−2}	Ø
parathion	75.950		
pentachloroethane	2458.000	:	
pentachlorophenol	27.630	•	
phenylene diamine	1171.000		
polychlorinated biphenyls	Ø.Ø61		
propylene dichloride	45.460		
styrene	582.499		
TCDD (tetrachlorodibenzo-p-dio)	Ø.31Ø	33	5.6×10^{-6}
tetrachloroethane(1,1,1,2)	7,135	5.8 × 10 ⁻⁵	2.3×10^{-7}
tetrachloroethylene	17,271	5.8 × 10 ⁻⁷	5.4×10^{-9}
thiourea	5	5.5 \times 10 ⁻⁴	1.5×10^{-9}
toluene diamine	21.718		
toxaphene	56	3.2×10^{-3}	9.8 x 10 ⁻⁸
trichloroethane(1,1,2)	18,458	1.6 × 10 ⁻⁵	1.6×10^{-7}
trichloroethylene	56,353	1.7×10^{-6}	5.2 x 10-8
trichlorophenol	30	5.7 x 10^{-6}	9.5×10^{-11}
vinyl chloride	626	4.1×10^{-6}	1.4 × 10 ⁻⁹
Total nationwide			
uncontrolled emissions	1,839,267	······	8.6×10^{-6}

^aLDR = Land disposal restrictions.

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 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 orderof-magnitude uncertainty factors that reflect various types of data used to estimate 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-3. Constituents were drawn from the Agency's final rule on the identification and listing of hazardous waste (Appendix VIII)⁹ and from several hazardous waste data bases.¹⁰ To be selected from these sources, the chemical must have had either an Agencyverified oral reference dose (as of September 30, 1987),¹¹ or a Reference Air Concentration (RAC) found in the Agency's proposed rule on the burning of hazardous waste in boilers and industrial furnaces.¹² Additional chemicals were added to Table E-3 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 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 <u>Human Exposure Model</u>

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

TABLE E-3. TSDF CHEMICALS - NONCANCER HEALTH EFFECTS ASSESSM
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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)

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

TABLE E-3 (continued)

Chemical	Chemical
methyl chloroform (1,1,1-	selenious acid (selenium dioxide)
trichloroethane) (71-55-6)	(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 iosbutyl 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
nickel refinery dust ^a (7440-02-2)	(95-94-3)
nitric oxide (10102-43-9)	1,1,1,2-tetrachloroethane ^a
nitrobenzene ^a (98-95-3)	(630-20-6)
4-nitroquinoline-1-oxide (56-57-5)	tetrachloroethylene ^a (127-18-4)
osmium tetroxide (20816-12-0)	2,3,4,6-tetrachlorophenol
pentachlorobenzene ^a (608-93-5)	(58-90-2)
pentachloroethane ^a (76-01-7)	tetraethyl dithiopyrophosphate
pentachloronitrobenzene (82-68-8)	(3689-24-5)
pentachlorophenol ^a (87-86-5)	tetraethyl lead (78-00-2)
phenol (108-95-2)	thallic oxide (1314-32-5)
m-phenylenediamine ^a (25265-76-3)	thallium (7440-28-0)
phenylmercuric acetate (62-38-4)	thallium (1) acetate (563-68-8)
phosgene (75-44-5)	thallium (1) carbonate (6533-73-9)
phosphine (7803-51-2)	thallium (1) chloride (7791-12-0)
potassium cyanide (151-50-8)	thallium (1) nitrate (10102-45-1)
potassium silver cyanide (506-61-6)	thallium (1) selenite (12039-52-0)
pronamide ^a (23950-58-5)	thallium (1) sulfate (10031-59-1)
propanenitrile (107-12-0)	thiomethanol (methyl mercaptan)
n-propylamine (107-10-8)	(74-93-1)
2-propyn-1-ol (107-19-7)	thiosemicarbazide (79-19-6)
pyridine (110-86-1)	

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	zinc cyanide (557-21-1)			
(75-69-4)	zinc phosphide (12037-79-5)			
2,4,5-trichlorophenol ^a (95-95-4)	zineb ^a (12122-67-7)			

TABLE E-3 (continued)

() = Chemical Abstracts Service (CAS) Number.

^aCarcinogen.

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 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.¹³

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 factor (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 °C 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. 14 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. Βv 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:

Total exposure =
$$\sum_{i=1}^{N} (P_i)(C_i)$$
 , (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 factor to estimate 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-3 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 hour, 3 hours, 8 hours, 24 hours, 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 factor 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 is discussed in Section E.4.1.2.

E.4.1.1 <u>Annual Cancer Incidence</u>. 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 value 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.¹⁵

A unit cancer potency factor of 1.0 and a unit emission rate of 10,000 g/yr were input to 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 factor and by the estimated VO emission that were attributed to each TSDF:

						Composite unit risk factor	VO emissions for TSDF XX		
Annual	incidence	=	HEM	annual	incidence x	<u> </u>	(10,000 kg	•	(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 <u>Maximum Lifetime Risk</u>. 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, ¹⁶ and it does not incorporate uncertainties in the exposure estimate or the risk factor.

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,

Maximum lifetime risk = $ \begin{cases} Composite unit risk \\ estimate at 1 \mu g/m^3 \end{cases} \times \begin{cases} ambient air \\ concentration \end{cases} $	aximum lifetime ri	k =	$ \begin{pmatrix} \text{Composite unit risk} \\ \text{estimate at 1 } \mu \text{g/m}^3 \end{pmatrix} $	x (Highest ambient air concentration)		(E-
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E.4.2 <u>Noncancer Health Effects</u>

E.4.2.1 <u>Chronic Exposures</u>. 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.

Until Agency-verified RFDs are available, an interim screening approach will be used. The likelihood of adverse noncancer health effects will be determined by comparing modeled ambient concentrations of individual constituents to the available health data. These health data are 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. Assessment of the potential for adverse noncancer health effects will be made case-bycase, 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 In general, the likelihood of noncancer health effects will be data base. considered to be low if modeled concentrations are several orders of magnitude below the health effect levels of concern. The probability that such effects will occur increases with increasing exposure concentrations. This screening effort will be 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 <u>Acute Exposures</u>. Assessment of the potential for noncancer health effects associated with short-term (acute) exposure to TSDF chemicals of concern at selected facilities is being 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, adequate acute inhalation data are limited for many of the TSDF chemicals of concern. The assessment is conducted by comparing maximum modeled ambient concentrations for averaging times of 15 minutes, 1 hour, 8 hours, and 24 hours to available short-term health data matched to the appropriate averaging time. Determination of the risk of adverse health effects associated with estimated short-term exposures is based on a consideration of the quality of the available health data and the proximity of the exposure concentration to the health effect level.

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. Nickel was selected as an example. The 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 <u>Federal Register</u> 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 factors 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 factor 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.¹⁷ 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 <u>Public Exposure</u>

E.5.2.1 <u>General</u>. 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 <u>The Public</u>. 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 inorganic arsenic 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 <u>Ambient Air Concentrations</u>. 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 is 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
 - 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.
- 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. 1984. p. 12-10.
- U.S. Environmental Protection Agency. Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Final Rule. 51 FR 28296. 1986.
- 10. Memorandum from Coy, Dave, RTI, to McDonald, Randy, EPA/OAQPS. May 2, 1986. Listing of waste constituents prioritized by quantity.
- U.S. Environmental Protection Agency. Status Report of the RfD Work Group. Environmental Criteria and Assessment office, Cincinnati, OH. 1987.
- U.S. Environmental Protection Agency. Burning of Hazardous Waste in Boilers and Industrial Furnaces; Preamble Correction. 52 FR 25612. 1987.
- 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.
- 14. Department of Commerce. Local Climatological Data. Annual Summaries with Comparative Data.

- 15. 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. p. 4-13.
- 16. Reference 15, p. 4-18.
- 17. U.S. Environmental Protection Agency. Guidelines for the Health Risk Assessment of Chemical Mixtures. 51 FR 34014. September 24, 1986.

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.

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 <u>Site 1</u>.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 m³. 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 $9,500 \text{ m}^3$.

F-4

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	l 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

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

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

^aThis table presents a summary of the air emission, liquid concentration, and biological activity testing conducted at TSDF surface impoundments.
	Area	Total			Mass tran	sfer coefficient,	x 10 ⁶ m/s		
Test site	tested, m ²	NMHC, Mg/yr	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, 198 June 22, 198	34C 34	16 61	Ø.2 2.4	Ø.2 1.0	Ø.7 8.4	1.2 2.6	Ø.9 12	Ø.3 Ø.4	NA NA
Site 7									
Holding pondd	4,860	1.2	2.3	2.8	3.1	<0.039	2.2	4.3	2.7
Reducing lagoon ^e	1,120	0.6	Б.Ø	Б.Б	12	7.6	5.7	2.6	4.9
Oxidizing Iagoon ^e	1,230	7.8	Ø,38	0.037	NA	35	NA	NA	NA

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

TSDF = Treatment, storage, and disposal facility.

NMHC = Nonmethane hydrocarbon.

NA = Not available.

^aThis 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.

^bDuring 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.

^cDuring 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.

^dField 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.

^eThe surface of the lagoon was coated with an oil film.

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

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

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

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

	Агеа	Total			Mass	transfer_coeff	icient, x 10 ⁶ m/s			
Test site	tested, m ²	NMHC,Ł Mg/yr	Tetralin	2-Ethy I hexano l	2-Ethyl hexylacrylate	Naphthalene	1,2- Dichloroethane	Benzene	Toluene	Ethy I benzene
Site 9										
Aeration tank	320	NA	NA	NA	NA	NA	NA	NA	180	NA
Site 11										
Covered aeration basin	5,940	NA	NA	NA	NA	NA	4.8	30	89	NA
Site 12										
Primary clarifiers	295	NA	230	43	130	88	2.2	19	52	39
Equalization	5,180	NA	NA	NA	NA	NA	16	8.6	38	Б.4
Aerated stabiliza- tion basins	29,200	NA	NA	Ø.7	120	NA	62	94	550	60

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

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

NMHC = Nonmethane hydrocarbon.

^aThis 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 9), vent measurements (Site 11), and ambient measurements and mass balance techniques (Site 12). .

^bTotal NMHC emission rates were not measured.

Site No.	Test site location	Test description	Test year	Test sponsor	Test duration
13	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
14	Gulf Coast commercial TSDF	Field test (1 landfill) • Flux chamber • Soil samples	1983	EPA/OSW	3 days
15	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

TABLE F-5. SUMMARY OF TSDF LANDFILL TESTING^a

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

^aThis table presents a summary of the air emission and soil concentration testing conducted at TSDF landfills.

,u	Area	Total			Emis	sion flux rate, ×	x rate, x 10 ⁶ g/m ² •s				
Test site	tested, m ²	NMHC, Mg/yr	Acetaldehyde	Methylene chloride	Toluene	1,1,1- Trichloroethane	Tetra- chloroethylene	Total xylene	Styrene	Ethylbenzene	
Site 13 Active LF	19,970	54	NA	NA	3.5	2.9	5.2	6.0	NA	1.6	
Site 6 Inactive LF	2,37Ø	0.056	NA	Ø.13	NA	0.071	NA	NA	NA	NA	
Active LF Temporary storage area	1,470	Ø.66	NA	0.43	0.073	2.6	Ø.65	Ø.65	NA	Ø.13	
Active working area	670	1.4	NA	9.5	NA	32	13	NA	NA	NA	
Site 14 Active LF Cell A	185	Ø.ØØ48	Ø.19	NA	<0.063	МА	NA	<0.13	<0.063	<0.063	
Site 15 Active LF-P	7,600	1.9	NA	1.6	Ø.42	Ø.21	1.0	Ø.79	NA	NA	
Inactive LF-0	Unknown	Ø.93	NA	NA	NA	NA	NA	NA	NA	NA	
Site 7 Inactive LF-A Vent 2A Vent 3-2	Unknown Unknown	0.044 0.0002	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	
Active LF-B Flammable cell	2,100	0.70	NA	0.089	Ø.94	1.7	2.6	Ø.86	0.20	Ø.26	
Organic cell	4,200	9.6	NA	Ø.73	3.7	Ø.45	Ø.Ø11	32	14	6.7	

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

TSDF = Treatment, storage, and disposal facility.

^aThis 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.

NA = Not available.

NMHC = Nonmethane hydrocarbon.

LF = landfill.

ite	Test site	Test	Test	Test	Test d	escription	Test	Waste	Emissions,
No.	location	description	уөаг	sponsor	Waste type	Application method	duration	constituent	wt % ^b
6	West Coast	Laboratory	1986-	Corporate	API separator sludge	Subsurface (Run 1)	69 d	011	40
		simulation	1987	research	API separator sludge	Subsurface (Run 2)	22 d	011	11
				facility	Centrifuged and dried API separator sludge	Subsurface (Run 2)	22 d	011	1
	Southwest	Laboratory simulation	1986	EPA/OAQPS	API separator sludge	Surface (Box #1 and 3) ^C (Box #2) ^d	31 d	0 i I 0 i I	Б.8 NA
						(Box #4)●		011	7.4
					IAF sludge	Surface (Box #1 and 3) ^C	31 d	011	18.5
					-	(Box #2)d		011	NA
						(Bo× #4)●		011	22
	Midwestern	Flux chamber	1985	EPA/ORD	API separator	Surface	1 wk	Benzene	94 f
	refinery	sampling of			DAF sludge			Toluene	53
		active land						Ethylbenzene	27Ø
		treatment						p-Xylene	29
		area						m-Xylene	Б1
								o-X ylene	33
								Naphthalene	1
	West Coast	Flux chamber	1984	EPA/ORD	DAF/API	Surface	Бwk	n-Heptane	60
	refinery	sampling of			Float50-75%,			Methylcyclohexane	61
		active land			Separator cleanings			3-Methyl-heptane	52
		treatment			20-30%,			n-Nonane	56
		area			Miscellaneous oily			1-Methylcyclohexene	49
					waste5%			1-Octene	5Ø
								A-Pipere	17
								Limonene	22
								Toluene	37
									35
								1 3 5-Trimethylbonzono	21
								a-Ethyl-taluana	20
								Total VO	32
									309
						Subsurface	ا سل	n-Hentana	1.2
						JUJJUTI ACO	O WK	Nethylayslaboxana	54
								2 Mothul bastane	00
								з-месну i-персане	11
								1 Nothylayalahaya	010 7.6
								1-Octobe	70
								1-000000	74
								D-Pinene	21

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

(continued)

Site	Test site	Test	Test	Test	Test o	lescription	– Test	Waste	Emissions, wt % ^b 26 56 48 27 42 369 1.4 9.1 4.4
No .	location	description	уөаг	sponsor	Waste type	Application method	duration	constituent	
19	West Coast refinery (con.)							Limonene Toluene p-,m-Xylene 1,3,5-Trimethylbenzene o-Ethyl-toluene Total VO Total oil	26 56 48 27 42 369 1.4
20	Southwest	Laboratory simulation	1983	API/EPA/ ORD	$\begin{array}{c} {\rm SL-14} & ({\rm Run \ No. \ 18})^{\rm h} \\ {\rm SL-11} & ({\rm Run \ No. \ 21}) \\ {\rm SL-14} & ({\rm Run \ No. \ 24}) \\ {\rm SL-11} & ({\rm Run \ No. \ 24}) \\ {\rm SL-11} & ({\rm Run \ No. \ 27}) \\ {\rm SL-14} & ({\rm Run \ No. \ 32}) \\ {\rm SL-11} & ({\rm Run \ No. \ 33}) \\ {\rm SL-11} & ({\rm Run \ No. \ 35}) \\ {\rm SL-12} & ({\rm Run \ No. \ 35}) \\ {\rm SL-14} & ({\rm Run \ No. \ 35}) \\ {\rm SL-11} & ({\rm Run \ No. \ 36}) \\ {\rm SL-12} & ({\rm Run \ No. \ 36}) \\ {\rm SL-14} & ({\rm Run \ No. \ 36}) \\ {\rm SL-12} & ({\rm Run \ No. \ 36}) \\ {\rm SL-13} & ({\rm Run \ No. \ 40}) \\ {\rm SL-13} & ({\rm Run \ No. \ 44}) \\ {\rm SL-13} & ({\rm Run \ No. \ 46}) \\ {\rm SL-13} & ({\rm Run \ No. \ 47}) \\ {\rm SL-13} & ({\rm Run \ No. \ 48}) \\ {\rm SL-13} & ({\rm Run \ No. \ 49}) \\ {\rm SL-13} & ({\rm Run \ No. \ 50}) \\ {\rm SL-13} & ({\rm Run \ No. \ 50}) \\ \end{array}$	Surface	8 h ⁱ	0:1 0:1 0:1 0:1 0:1 0:1 0:1 0:1 0:1 0:1	9.1 4.4 0.02 0.6 0.1 3.0 2.8 0.01 0.9 78.8 9.9 0.7 2.8 4.9 49.9 7.7 8.9 5.0 9.7 1.1 0.47
14	Gulf Coast commercial TSDF	Flux chamber sampling of active land treatment	1983	EPA/ORD	Aged wastej	Surface	69 h 50 h	Total VO ^k Benzene	Ø.77 3.91
21	Midwestern refinery	Flux chamber sampling of test plots	1979	API	Sludge from centrif- ugal dewatering of oily sludges from refinery operations and wastewater treatment	Surface	19.9 հ 307 հ	0il 0il	Ø.1 ¹ 2.5 ^m

TABLE F-7 (continued)

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TABLE F-7 (continued)

Site	Test site	Test	Test	Test	Test de	escription	Test	Waste	Emissions,
No.	location	description	year	spansor	Waste type	Application method	duration	constituent	wt %b
21	Midwestern refinery (con.)				API separator sludge ⁿ	Surface	619 h 122 h 520 h	0;1 0;1 0;1	13.6° 1.1P 13.69

$$\begin{split} TSDF = Treatment, storage, and disposal facility.\\ API = American Petroleum Institute.\\ NA = Not applicable\\ DAQPS = Office of Air Quality Planning and Standards.\\ ORD = Office of Research and Development. \end{split}$$

IAF = Induced air flotation.

DAF = Dissolved air flotation.

•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.

bWeight percent is the fraction of the organic waste constituent emitted during the test.

CAverage of Boxes #1 and #3. Sludge was applied to Box #1 and Box #3 as duplicate tests.

^dControl--no sludge added.

^eMercuric chloride was added to sludge/soil mixture in an attempt to eliminate biological activity.

^fThe 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:

	30100010 810 810 83 1011083.
Benzene Ø.58 - 1.30	m-Xylene Ø.25 - Ø.77
Toluene Ø.29 - Ø.78	o-Xylana Ø.20 - Ø.46
Ethylbenzene 1.63 - 3.65	Naphthalene 0.01 - 0.02
p-Xvlene Ø.12 - Ø.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.

9The concentration of volatile organics was determined using the purge and trap technique. Analysis was performed on a Varian 3700 gas chromatograph.

hEach 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 studge.

 $SL-13 \approx Mixture of API separator bottoms, DAF froth, and biological oxidation sludge.$

SL-14 = API separator sludge.

¹Each run for which results are reported was 8 hours.

)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.

^kDetermined using purge and trap techniques and analyzed using a Varian Model 3700 gas chromatograph.

Test 5. Emissions following application of waste to test plot.

^mTest 8. Emissions following rototilling at the end of Test 6 on the same test plot.

ⁿWaste was weathered for 14 days in open 5-gal buckets in an outdoor open shelter prior to application.

"Test 7. Emissions following application of waste to test plot.

PTest 8. Emissions following application of waste to test plot.

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

								Test results	Emission rate, x 10 ⁶ , Mg/yr NA NA NA NA NA NA NA NA NA NA NA NA NA
Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Source tested	Total hydrocarbons, ^b ppm	Waste constituent	Emission rate, × 10 ⁶ , Mg/yr
6	California commercial	Ambient monitoring	1984	EPA/0AQPS	1 d	Vicinity of tank storage	0.2	NA	NA
	TSDF	. 5				Drum storage area	0.0	NA	NA
						Drum transfer area	0.0	NA	NA
						PCB building	Ø.1	NA	NA
22	Eastern commercial	Ambient monitoring	1983	EPA/OAQPS	1 wk	Upper drum storage area			
	chemical conversion					East side, Ø.3 m from drums	60	NA	NA
	and reclaim-	-				East side, 6.1 m	7	NA	NA
	ing raciitoj	,				South side, 2.4 m	5	NA	NA
						West side, 2.4 m	5-7	NA	NA
						from drums North side, 1.5 m from drums	10-20	NA	NA
						Lower drum storage area			
						East side, 2.4 m	10-20	NA	NA
						South side, 2.4 m	20-30	NA	NA
						West side, 2.4 m	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 Toluene Total Xylene Naphthalene Methylane chloride 1,1,1-Trichloroetham Carbon tetrachloride Tatrachloroethylene	150,000 2,300 1,000 560 80,000 e 4,500 3,500 45 000

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

TSDF = Treatment, storage, and disposal facility. DAQPS = Office of Air Quality Planning and Standards.

PCB = Polychlorinated biphenyls.

NA = Not available.

NMHC = Nonmethane hydrocarbon.

^aThis table presents a summary of the air emission testing conducted at TSDF transfer, storage, and handling operations. bAmbient measurements by organic vapor analyzer.

							-	Test	results	
Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Constituent	Organic removal efficiency, %	Process vent emissions Mg/yr
Captu	re and containm	ent								
11	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 struc- ture perimeter with a portable hydro- carbon analyzer ^b	NA	NA	NA
Add-o	n control devic	es								
23	Pennsylvania NPL Super- Fund site	Field test • Vent samples • Liquid samples	1985	EPA Region III	4 days	Gas-phase activated carbon bed used to control over- head effluent from air stripper treating leachate	Vent sampling of influent to and effluent from gas- phase activated carbon bed	1,2,3-Trichloropropane (o,m)-Xylene p-Xylene Toluene Ethylbenzene 1,2-Dichlorobenzene Other VO Total VO ^C	99.999 99.95 99.9 99.9 99.9 99.9 99.9 9	NA NA NA NA NA NA
11	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 lagoond	Vent sampling of influent to and effluent from gas- phase activated carbon bed on August 18, 1984 First set of vent sampling of influ- ent to and efflu- ent from gas-phase activated carbon bed on August 17, 1984	Methylene chloride 1,2-Dichloroethane Benzene Toluene Chlorobenzene Chloroform NMHC ^e Methylene chloride 1,2-Dichloroethane Benzene Toluene Chlorobenzene Dichlorobenzene Chloroform NMHC ^e	51.2 -47.9 -17.0 41.3 $-2,100.0$ 91.7 58.3 -15.0 -6.0 -0.5 12.3 -31.6 -0.8 -33.3 5.5 4.0	NA NA NA NA NA NA NA NA NA NA NA NA NA N

TABLE F-9. SUMMARY^a OF TSDF CONTROLS TESTING

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(continued)

								Test	results	
Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Constituent	Organic removal efficiency, o Constituent %	Process vent emissions Mg/yr
11 (c	on .)						Second set of vent sampling of influ- ent to and efflu- ent from gas-phase activated carbon bed on August 17, 1984	Methylene chloride 1,2-Dichloroethane Benzene Toluene Chlorobenzene Dichlorobenzene Chloroform NWHC ^e	0.0 -34.3 -236.0 -284.0 -03.3 60.0 1.8 -42.8	NA NA NA NA NA NA
							Vent sampling of influent to and effluent from gas- phase activated carbon bed on July 17, 1984	1,2-Dichloroethane Benzene Toluene Chlorobenzene NMHC ^e	0.0 -8.3 34.3 -45.8 -8.8	NA NA NA 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 Benzene Toluene Chlorobenzene Chloroform NMHC ^e	100.0 100.0 100.0 100.0 100.0 53.5	NA NA NA NA NA
5	Mississippi chemical manufacturing plant	Field test • Vent samples • Liquid samples	19 85	EPA/ORD	1 day	Liquid-phase carbon adsorption used to treat steam-stripped wastewater	Liquid sampling of the carbon adsorber influent and effluent	Nitrobenzene 2-Nitrotoluene 4-Nitrotoluene Total VO ^C	>98.0/ >67.0/ >82.0/ >95.0/	NA NA NA
24	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 con- denser and meas- uring flow rates at these points.	Chloromethane Methylene chloride Chloroform Carbon tetrachloride Total VO ^C	88.6 90.0 94.4 89.6 90.9	NA NA NA NA

TABLE F-9 (continued)

See notes at end of table.

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								Test	results	
Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Constituent	Organic removal efficiency, %	Process vent emissions Mg/yr
25	Texas	Field test	1986	EPA/ORD	2 days	Condenser system (primary	Sampling of the	Vinyl chloride	6.0	NA
	chemical	• Vent samples				water cooled: secondary	vapor and liquid	chloroethane	47.0	NA
	manufacturing plant	• Liquid samples				glycol cooled) used to recover VO steam stripped from wastewater	condensate from the secondary con- densor and meas- uring flow rates at these points	1,1-Dichloroethene 1,1-Dichloroethene 1,2-Dichloroethene Chloroform 1,2-Dichloroethene	15.0 88.0 84.0 96.0 99.5	NA NA NA NA
Volat	ile organic remo	val processes								
24	West Virginia	Field test	1988	EPA/ORD	2 davs	Steam stripper used to	Liquid sampling	Chloromethane	>99.98	0.51
	chemical	• Vent samples		•		strip organics from waste-	of stripper feed.	Methylene chloride	>99.999	39.4
	manufacturing plant	• Liquid samples				water	bottoms, and con- densate and vent sampling of pri- mary and secondary condenser vents	Chloroform Carbon tetrachloride Trichloroethylene 1,1,2-Trichloroethane	>99.999 >99.98 >99.8 >99.8	12.1 4.9 NA NA
25	Texas	Field test	1988	EPA/ORD	2 days	Steam stripper used to	Liquid sampling of	1,2-Dichloroethane	99.998	11
	chemical	 Vent samples 				strip organics from	the stripper	Chloroform	96.Ø	3.5
	manufacturing plant	• Liquid samples				wastewater	influent and effluent and from the overhead aque- ous and organic condensate. Vent sampling of sec- ondary condenser vent	Benzene Carbon tetrachloride Chlorobenzene Chloroethane 1,1-Dichloroethane 1,2-Dichloroethane 1,2-Dichloroethane Methylene chloride Tetrachloroethane Trichloroethane Vinyl chloride Total V0°	>95.0 >99.4 97.0 >99.9 >99.9 >99.9 >99.9 >99.2 >99.3 >99.9 >99.8 >99.9 >99.8	NA NA 1.4 0.41 0.98 0.31 NA NA NA NA 2.8 20

TABLE_F-9 (continued)

See notes at end of table.

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			Test year	st Test ar sponsor				Test	results	
Site No.	Test site location	Test description			Test duration	Control tested	Test identification	Constituent	Organic removal efficiency, %	Process vent emissions Mg/yr
5	Mississippi	Field Test	1985	EPA/ORD	1 day	Steam stripper used to	Liquid sampling	Nitrobenzene	91.4	<0.0011
	chemical	• Vent samples			· •	strip organics from waste-	of the stripper	2-Nitrotoluene	96.7	<0.0011
	manufacturing plant	♥ Liquid samples				water from production pri- marily of nitrated aroma- tics and aromatic amines	influent and effluent and from the overhead aque- ous and organic condensates. Vent sampling of condensate tank vent	4-Nitrotoluene Total VOC	90.9 92.0	<0.0011 <0.0033
26	Organic	Field test	1984	EPA/ORD	3 days	Steam stripper used for	Sampling during	Acetone	91.0	NA
	solvent	• Vent samples				organic solvent reclama-	four batches.	Isopropanol	99.6	0.0045
	recycling	Liquid samples				tion from contaminated	Liquid sampling	Methyl ethyl ketone	96.Ø	0.019
	plant					organics generated by the	of stripper influ-	1,1,1-Trichloroethane	87.0	0.0042
						centical plastics and	miscible solvent	Ethyl benzene	96,0 99,1	0.0023
						heavy manufacturing indus-	tank, and recov-	Toluene	99.6	0.016
						tries	ered VO storage	Xylene	99.5	0.0085
							tank. Vent sam- pling of condenser vent. Batch 1: aqueous xylene	To tal VOC	99.4	0.058
							Batch 2: 1.1.1-	1.1.1-Trichloroethane	99.8	0.0019
							trichloroethane/	Methyl ethyl ketone	100.0	0.077
							011	Total VOC	99.8	0.079
							Batch 3: aqueous	1,1,1-Trichioroethane	94.0	NA
							1,1,1-trichloro-	Methyl ethyl ketone	99.0	NA
							etnane	Acetone Ethul benzone	99.0 74.0	NA
								Isopropanol	(85.0	NA
								Total VOC	94.0	NA
							Batch 4: aqueous	Acetone	99.96	NA
							mixed solvents	1,1,1-Trichloroethane	90.0	NA
								lotal VU~	96.0	NA

TABLE F-9 (continued)

F-18

(continued)

See notes at end of table.

			· ··			TABLE F-9 (Continued)				
								Test	results	
te lo.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Constituent	Organic removal efficiency, %	Process vent emissions, Mg/yr
7	Chemical	Field test	1984	EPA/ORD	2 days	Steam stripper used to	Liquid sampling	Methylene chloride	>99.99	1.4
	manufacturing	• Vent samples				remove VD, especially	of stripper influ-	Chioroform	91.0	0.013
	plant	• Liquid samples				methylene chloride, from aqueous streams	ent, effluent, and organic overhead condensata. Vent sampling from product receiver tank vent	Carbon tetrachloride Total VO ^c	NA 99.8	0.0047 1.4
3	Pennsylvania	Field test	1985	EPA	4 days	Air stripper used to treat	Test yielding	1,2,3-Trichloropropane	>98	<0.0000013
	NPL Super-	• Vent samples		Region III	•	leachate from closed	highest VO removal	(o,m)-Xylenes	>96	0.000023
	Eurod cito	• Liquid nomeles				1	f	p-Xylene	>88	0.000015
		Erdurd sampres				Tagoons	Liquid samples of	Toluene	NA	0.000014
							air stripper	Aniline	63	NA
							influent and	Phenol	>53	NA
							effluent	2-Methylphenol	708	NA
								4-Methylphenol	>53	NA
								Ethylbenzene	NA	0.0000038
								1.2-Dichlorobenzene	>71	0.0000012
								1,2,4-Trichlorobenzene	>69	NA
								Other VO	30	0.0000051
								Total VOC	>99	0.000064
							Test under stand-	1,2,3-Trichloropropane	6.9	NA
							ard operating	(o,m)-Xylenes	57	NA
							conditions.9	p-Xylene	46	NA
							Liquid samples of	Toluene	46	NA
							air stripper	Aniline	38	NA
							influent and	Phenol	52	NA
							effluent	2-Methylphenol	29	
								1,4-Dichlorobenzene	40	NA
								1,2-Dichlorobenzene	51	NA
								ether	>62	NA
								2,4-Dimethylphenol	34	NA
								1,2,4-Trichlorobenzene	52	NA
								Ethylbenzene	89	NA

TABLE F-9 (continued)

See notes at end of table.

(continued)

						TABLE F-9 (continued)				
			· ·					Test	results	
Síte No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Constituent	Organic removal efficiency, %	Process vent emissions, Mg/yr
23 (con.)							Chlorobenzene Ethane,1,1-oxybis[2- ethoxy] Other VD	67 4.1 45	NA NA NA
_								Total VO ^c	25	NA
28	Thin-film evaporator	Pilot-scale tests • Vent samples	1986	EPA/HWERL	1 week	Thin-film evaporator used	Liquid sampling of evaporator	Benzene Toluene	99.76 99.90	NA NA
	manufacturing plant	• Liquid samples				wastes	feed, bottoms, and condensate. Vent samples collected, but vent gas flow rate not measured	Ethylbenzene Styrene m-Xylene o,p-Xylene Phenol Benzyl alcohol 2-Methylphenol 4-Methylphenol 2,4-Dimethylphenol bis(2-Ethylhexyl) phthalate Naphthalene Acenaphthalene Acenaphthylene Acenaphthylene Dibenzofuran Fluorene Phenanthrene Anthracene Chrysene Benzo (a)anthracene Chrysene Benzo fluoranthened Benzo (a)pyrene	99.78 99.25 99.75 99.74 NA NA NA NA NA NA NA NA NA NA NA NA NA	NA N
29	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,	Acetone Ethyl acetate Methyl isobutyl ketone Dubul alastad	99 >45 80	NA NA NA
							and condensate. Gas samples col- lected but vent velocities not measured	n-Butyi alcohol Toluene Methyl ethyl ketone Isopropanol Total VO ^C	>75 82 84 >96 74	NA NA NA NA

See notes at end of table.

F-20

(continued)

								Test	results	
ite No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Constituent	Organic removal efficiency, %	Process vent emissions Mg/yr
3Ø	Organic	Field test	1984	EPA/ORD	1 day	Thin-film evaporator used	Liquid sampling of	Acetone	76	NA
	solvent	• Vent samples				in reclamation and recycle	evaporator feed,	Xylene	30	NA
	recycling plant	• Liquid samples				of organic solvents from the chemical, plastics, paint, adhesive film, electronics, and photo- graphic industries	bottoms, and con- densate. Vent sampling of con- denser vent.	1,1,1-Trichloroethane Toluene Tetrachloroethylene Trichloroethylene Freon TF Ethylbenzene Total VO ^c	82 82 54 93 72 <85 73	NA NA NA NA NA NA
22	Organic	Field test	1984		1 day	This_film evenesates used	Liquid complian	Nathylana ablasida	99.1	NA
22	chemical	• Voot complee	1904	EFAJURD	I day	Inin-film evaporator used	Liquid sampling	Methylene chloride	99.1	NA
	Chemical	• Liquid samples				to process organic wastes	of evaporator)99.99)99.99	INA NA
	plant	- Liquid sampies				trom the turniture, chemi- cal, dry cleaning, and paint industries	influent, bot- toms, and conden- sate. Vent sam- pling of vacuum pump vent	l,l,l-Irichioroethane Toluene Freon TF	>99.6 <85.0 90	NA NA NA
29	Texas solvent	Field test	1986	EPA/ORD	4 days	Azeotropic steam injection	Field testing on	Tetrachioroethylene	89	NA
	recycling	 Vent samples 				distillation unit used to	two batches,	Methylene chloride	92	NA
	facility	• Liquid samples				purify chlorinated solvents	Liquid sampling of waste feed, final injection	Carbon tetrachloride Trichloro- trifluoroethane	>8Ø >87	NA NA
							kettle residue,	Xylenes	38	NA
							and overhead	Ethyl acetate	82	NA
							organic and aque- ous condensates. Gas samples col- lected but vent gas velocities not measured. Batch 1: methyl- ene chloride as major constituent	Total VOC	36 76	NA NA
							Batch 2: 1,1,1-	Trichloroethylene	>21	NA
							trichloroethane	Methylene chloride	>51	NA
							as major constit- uent	1,1,1-Irichloroethane Trichloro- trifluroethane	91 >51	NA NA
								Isopropanol	>12	NA
								Total VOC	91	NA

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(continued)

TABLE F-9 (continued)

								Test	results	
Site No.	Test site location	Test description	Test year	Test sponsor	Test duration	Control tested	Test identification	Constituent	Organic removal efficiency, %	Process vent emissions, Mg/yr
31	Organic	Field test	1984	EPA/ORD	2 days	Batch distillation used in	Field testing on	Methyl ethyl ketone	>99.97	2.5
	chemical	Vent samples				reclamation of contaminated	two units. Lig-	2,2-Dimethyl oxicane	>99.8	0.52
	recovery plant	• Liquid samples				solvents and other chemicals from the chemical, paint, ink, recording tape, adhe- sive film, automotive, air- lines, shipping, electronic, iron and steel, fiberglass, and pharmaceutical indus- tries	uid sampling of charge to reboil- er, final aqueous residue from re- boiler, and final overhead conden- sate. Vent sam- pling of condenser receiver, and product accumu- lator vents, Unit 1	methanol Methylene chloride Isopropanol Carbon tetrachloride 1,1,1-Trichloroethane Other VO Total VO ^C	>99.7 >99.7 >99.5 >99.4 29.0 >98.0 >98.0	0.30 0.26 0.16 0.14 0.017 0.17 4.1
							Unit 2	Acetone 99.7 Trichloroethane 1,1,1-Trichloroethane	0.074 >99.9 >99.7	0.0034 0.00098 0.00095
								Methyl ethyl ketone	>99.6	0.00080
								Isopropanol	98.0	0.00015
								Aromatics	97.0	0.00010
									99.8	0.080

TSDF = Treatment, storage, and disposal facility.

ORD = Office of Research and Development.

NMHC = Nonmethane hydrocarbon.

VO = Volatile organics.

^aThis 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.

^bMeasured 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 m³/s (300 cfm).

CTotal VO removal efficiency represents weighted average removal efficiency for the listed constituents.

^dBeds originally designed for odor control, specifically for removal of orthochlorophenol.

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

^fHighest 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 m³/min (170 ft³/min), giving the highest air:water ratios observed during testing.

9Under 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 m³/min (60 ft³/min).

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

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

TSDF = Treatment, storage, and disposal facility.

 $^{a}\mbox{Length}$ 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 $26,000 \text{ m}^3$, 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 624² 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

		Con	centratior	n, µ g∕L	
- Constituent	Pond 2 aerobic sample	Pond 6 aerobic sample	Por dupl aerobic	nd 8 icate samples	Pond 8 anaerobic sample
Methylene chloride	1,850	46 ^b	47b	36 ^b	44b
Chloroform	880 ^b	22b	2.3 ^b	2.5 ^b	<50
1,1,1 - Trichloroethane	16,000	30p	<50	<50	<50
Tetrachloroethene	<50	<50	22b	24b	<50
1,1,2,2-Tétrachloroetha	ne <50	15 ^b	<50	<50	<50
Benzene	<50	gb	<50	<50	<50
Toluene	2,070	33p	43b	46 ^b	47b
Ethyl benzene	<50	11b	12 ^b	15 ^b	<50
Chlorobenzene	42b	7b	2p	Зp	3p
Acetone ^C	35,000	5,450	4,500	4,200	4,100
Isopropano] ^C	156,000	8,400	4,200	3,200	3,200
1-Butano1 ^{b;c}	71,300	510	<50	<50	<50
Thiobis methane^C	<50	<50	1,300	1,300	1,500
Freon 113 ^C	<50	<50	40 ^b	23 ^b	49b
Methyl ethyl ketone ^C	27,000	210	510	490	620
Total xylenes ^C	1,140	<50	47b	49b	<50

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

TSDF = Treatment, storage, and disposal facility.

^aDetermined by EPA Method 624.

^bIndicates concentration is below the reportable quantitation limit. These compounds were positively identified, but the accuracy of quantitation is not guaranteed within 30 percent.

^CIndicates 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).

		Cond	centration	, μ g/L	
Constituent	Pond 2 aerobic sample	Pond 6 aerobic sample	Pon dupl aerobic	d 8 icate samples	Pond 8 anaerobic sample
Bis (2-chloroisopropyl) ether	17,600	76b	68b	<200	148b
Bis (2-ethylhexyl) phthalate	6,560	78 ^b	43b	<200	<200
Isophorone	72,800	5,600	34b	75 ^b	160 ^b
2-Nitrophenol	<1,000	660	670	490	800
N-Nitrosodiphenylamine	<4,000	35b	35b	40b	137 ^b

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

TSDF = Treatment, storage, and disposal facility.

^aDetermined by EPA Method 625.

^bIndicates 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

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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 BODtype 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 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 <u>Site 2.4</u> Site 2 is primarily engaged in the treatment and disposal of dilute (less than 10 percent organic) aqueous wastes generated

	Zero-order x 10 ³	biorates, ^a mg/g-h	First-order biorates, x 10 ³ L/h		
Constituent	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		

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

TSDF = Treatment, storage, and disposal.

^aThe 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 $81,000 \text{ m}^2$ 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 inor-ganic 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

		Conce	ntration,	µg/L	
Constituent	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	BQLe	11,000	12,000
Chloroform	BQLd	BQLq	BQLe	110	BQLc
1,2-Dichloroethane	BQLd	BQLd	BQLe	120	BQLc
1,1,1-Trichloroethane	e BQLd	BQLq	BQLe	1,300	760
Tetrachloroethane	BQLd	BQLd	BQLe	130	640 ^c
Freon 113 ^b	BQLd	BQLd	BQLe	550	370
Toluene	35 ^c	40 ^c	7.5 ^c	890	3,000
Ethyl benzene	BQLd	BQLd	BQLe	170	100
Total xylenes ^b	56 ^C	70 ^c	BQLe	820	430
Benzene	BQLd	BQLd	BQLe	60 ^c	69C

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

TSDF = Treatment, storage, and disposal facility.

^aDetermined by EPA Method 624.

^bIndicates nontarget compounds quantitated using a response factor from a single-point calibration.

^CCompound identified below strict quantitation limit; accuracy of reported concentration not ensured to be within 30 percent.

^dBelow method quantitation limit of 100 μ g/L.

^eBelow method quantitation limit of 10 μ g/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 widemouth, 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 <u>Site 3.5</u> 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

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

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

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

^aThe 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.

^bOxygen uptake rates were determined by using a least squares linear regression on the data.

^CThe 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 μ g/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 <u>Site 4</u>.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 $243,000 \text{ m}^2$ 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 μ g/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.

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	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

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

TSDF = Treatment, storage, and disposal facility.

^aThis 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 waterfilled 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 <u>Site 5</u>.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 m². 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 <u>Site 6.15</u> 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.

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

TABLE F-17. SOURCE TESTING RESULTS FOR TSDF SITE 5, WASTEWATER HOLDING LAGOON¹²

TSDF = Treatment, storage, and disposal facility.

NMHC = Nonmethane hydrocarbon.

 $^{\rm a}{\rm Average}$ of emission rates measured with a flux chamber at Grid Points A, B, E, F, and the SW corner.

^bAverage of concentrations measured from liquid samples taken at Grid Points A, B, E, F, and the SW corner.

^CCalculated from measured emission rates and liquid concentrations.

^dThe NMHC totals do not represent column sums because only constituents detected in gas and liquid samples are presented.

			Constituent concentration ^C			
Sample	Sample	Sample	Nitro-	2,4-Dinitro-	4,6-Dinitro-	Benzene
location ^b	type	depth, m	benzene	phenol	o-cresol	
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

TABLE F-18. STRATIFICATION STUDY RESULTS^a FOR TSDF SITE 5, WASTEWATER HOLDING LAGOON¹³

TSDF = Treatment, storage, and disposal facility.

^aThis 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.

^bSampling grid (A, B, E, and F) and sample number at each depth within the grid (1, 2, 3, 4, and 5).

^CConcentration results are gas chromatography-flame ionization detector analyses, in mg/L for liquids and mg/kg for sludges.

dSample contaminated with sludge.

	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 2,4-Dinitrophenol 4,6-Dinitro-o-cresol Benzene	560 mg/L 460 mg/L 38 mg/L 22 mg/L	88,000 mg/kg 9,300 mg/kg 4,000 mg/kg 1,200 mg/kg	
Estimated weight of waste constituent			
Nitrobenzene 2,4-Dinitrophenol 4,6-Dinitro-o-cresol Benzene	2,500 kg 2,000 kg 170 kg 100 kg	360,000 kg 38,000 kg 16,000 kg 4,900 kg	144 19 94 49
		Aver	age = 77

TABLE F-19. SLUDGE:LIQUID ORGANIC CONTENT COMPARISON FOR TSDF SITE 5, WASTEWATER HOLDING LAGOON¹⁴

TSDF = Treatment, storage, and disposal facility.

^aAverage 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 <u>Site 7</u>.^{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.

Constituent	Mean	Mean	Mass transfer
	emission rate,	liquid concentration,	coefficient, ^b
	Mg/yr	mg/L	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	<u>.</u>		
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

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

TSDF = Treatment, storage, and disposal facility.

NMHC = Nonmethane hydrocarbon.

^aAir emissions were sampled with a flux chamber and liquid concentrations were determined from grab samples.

^bCalculated from measured emission rates and liquid concentrations.

^CDuring 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.

^dThe 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-m³ 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-m³ 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-m³ 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 <u>Wastewater Treatment</u>

F.1.2.1 <u>Site 8</u>.¹⁹ Site 8 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 UNOXactivated 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.

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

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

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

^aAir emissions were sampled with a flux chamber and liquid concentrations were determined from grab samples.

^bCalculated from measured emission rates and liquid concentrations.

^CThe NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

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

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

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

^aAir emissions were sampled with a flux chamber and liquid concentrations were determined from grab samples.

^bCalculated from measured emission rates and liquid concentration.

^CThe NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

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

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

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

^aThis 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.

^bThe 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.

^cCalculated from measured emission rates and waste concentration.

^dThe NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.

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, 20 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 μ g/ (g•biomass-h), respectively.

F.1.2.2 <u>Site 9</u>.²¹,²² Site 9 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, aboveground, 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-24 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

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

TABLE F-24. AIR EMISSIONS AND MIXED-LIQUOR COMPOSITION IN THE AERATION TANK AT SITE 9^a

NM = Not meaningful.

VOC = Volatile organic compound.

^aAir 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.

^bCalculated from measured emission rates and liquid concentration.

^CVolatile organic compounds containing two carbons, e.g., ethane.

^dAcetone measurements from the tank surface did not exceed blank concentration levels.

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.

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-25. Multiple rates for the same compound reflect data obtained during different tests. Taking the rate constant for phenol, as an example, as $0.25 \ \mu g/min-g$ biomass, would imply that a tank with mixed-liquor volatile suspended solids of 2,500 mg/L could effectively biodegrade 5,400 $\mu g/L$ of phenol. The actual difference between phenol in the influent and the effluent of the aeration tank during the study period averaged 6,200 $\mu g/L$

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

TABLE F-25. BIODEGRADATION RATE CONSTANTS OBSERVED IN SHAKER TESTS CONDUCTED AT SITE 9 AERATION TANK^a

TSDF = Treatment, storage, and disposal facility.

^aThis table presents zero-order biodegradation rate constants determined from analyses of shaker test samples at Site 9. Where more than one rate is presented, data were obtained from different tests conducted during a 1-week period. (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 μ g/L.

F.1.2.3 <u>Site 10</u>.²³ The Site 10 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.

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 $4,000 \text{ m}^2$. 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 10 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 aliguots 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).²⁴ Table F-26 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 μ L 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

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		
5/20/86	1000	0.67	8.2	4.0	6/5	lotal BOD
5/20/86	1000	0.5	8.2	4.6	605	
5/20/86	1000	0.67	8.2	4.0	685	Inhibited BOD
Method	blank	NA	8.2	8.0		300 mL of dilutior
Method	blank	NA	8.2	8.0		water

TABLE F-26. BIOCHEMICAL OXYGEN DEMAND RESULTS^a FROM EQUALIZATION BASIN AT TSDF SITE 10²⁵

TSDF = Treatment, storage, and disposal facility.

DO = Dissolved oxygen.

BOD = Biological oxygen demand.

NA = Not applicable.

^aGrab 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.

^bBOD is calculated as follows: BOD = [(Initial DO - Final DO)/Aliquot %] x 100. 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-27 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 when their respective holding time had elapsed. Table F-28 presents the results of the DO analyses.

F.1.2.3 <u>Site 11</u>.²⁸ The Site 11 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-m³ 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.

Sample date	рН	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

TABLE F-27. ACRYLONITRILE CONCENTRATIONS OF THE EQUALIZATION BASIN SPIKED SAMPLES^a AT TSDF SITE 10²⁶

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

^aGrab 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 μ L of stock acrylonitrile. This table presents the results of the analyses of the three sets of spiked samples.

		Mean	Mean	Mean	Mean total
Sample date	рH	initial DO, mg/L	final DO, mg/L	percent reduction	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

TABLE F-28. DISSOLVED OXYGEN DATA FOR EQUALIZATION BASIN SAMPLES^a AT TSDF SITE 10²⁷

TSDF = Treatment, storage, and disposal facility. D0 = Dissolved oxygen.

^aGrab 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.

The aerated lagoon at Site 11 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 pressurized by a main blower and equipped with an emergency fan, a propanepowered 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 11 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 2.²⁹ Average gas velocity was determined following procedures outlined in Reference Method 1.³⁰ 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-29 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.1.2.4 <u>Site 12</u>.^{31,32} Site 12 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 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

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-Dichloro- ethane	29	4.2	27	3.5	160	20	38	4.8
Benzene	39	Ø.6Ø	39	3.2	230	18	380	30
Toluene	9.1	0.28	8.9	4.6	51	25	180	89

TABLE F-29. SOURCE TESTING RESULTS[®] FOR TSDF SITE 11, COVERED AERATED LAGOON

TSDF = Treatment, storage, and disposal facility.

^aTo perform the materials balance analysis, numerous liquid and slurry samples were collected at various locations around the Site 11 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.

 $^{
m b}$ The mass transfer coefficient is emission flux rate divided by outlet concentration.

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-30. 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-fourhour composite samples of the wastewater were collected from the influent to the treatment plant, the effluent from the primary system, the effluent

TABLE F-30. PHYSICAL PARAM SITE 12, WASTEWATE	ETERS OF PROCESS UNITS AT TSDF R TREATMENT SYSTEM ³³
Inlet box & pH adjustment tanks	 Two 61-m³ 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 paralleltwo 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 paralleleach holds 11 Mg, 3.7 m deep (MLSS 1,500 to 3,000 mg/L) Aerators3.7 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. 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.

Tables F-31, F-32, and F-33 summarize the test results from the primary clarifiers, equalization basin, and aerated stabilization basins, respectively.

F.1.3 Landfills

F.1.3.1 <u>Site 13</u>.³⁴ Site 13 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 13 on October 11 and 23, 1983. The open landfill covered approximately 19,970 m² 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

Constituent	Influent rate to clarifiers, 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
Tetralin ^c	Ø.8	Ø.1	<0.0	Ø.3	NA	28	NA	23Ø
2-Ethyl hexanol ^c	72	22	20	8.8	2,200	95Ø	100	43
2-Ethyl hexyl- acrylate ^c	13	1.8	<0.0	2.1	NA	230	NA	130
Naphthalene ^c	3.8	Ø.8	1.3	Ø.7	140	7Ø	180	88
1,2-Dichloro- ethane ^d	1.2	Ø.5	Ø.3	0.01	32	1.1	64	2.2
8enzene ^d	40	18	0.8	2.8	89	300	5.6	19
Toluened	8.1	2.9	Ø.9	1.4	100	150	34	52
Ethyl benzene ^d	27	6.9	10	2.5	1,100	270	160	39

TABLE F-31. SOURCE TESTING RESULTS^a FOR TSDF SITE 12, PRIMARY CLARIFIERS

TSDF = Treatment, storage, and disposal facility.

NA = Not available.

^aTwenty-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.

^bThe mass transfer coefficient is emission flux rate divided by outlet concentration.

^CAir emissions were measured for the low volatility compounds on August 18, 1983. Influent rate and outlet concentration measurements correspond to the air emission measurements.

^dAir 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.

Constituent	Influent rate to basin, Mg/yr	Outlet	_ Emission rate, Mg/yr_		Emission flux rate, x 10 ⁶ g/m ² ·s		Mass transfer coefficient, ^b x 10 ⁶ m/s	
		concentration, mg/L	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	NĂ
Naphthalenec	NA	NA	NA	NA	NA	NA	NA	NA
1-2,Dichloro- ethane ^d	1.5	Ø.3	0.9	Ø.8	5.5	4.9	18	16
Benzened	40	7.1	23	10	140	61	20	8.6
Toluened	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

TABLE F-32. SOURCE TESTING RESULTS³ FOR TSDF SITE 12, EQUALIZATION BASIN

TSDF = Treatment, storage, and disposal facility.

NA = Not available.

^aTwenty-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.

 $^{
m b}$ The mass transfer coefficient is emission flux rate divided by outlet concentration.

^CAir emissions reportedly were measured for the low volatility compounds on August 12, 1983, but were not presented in the report.

^dAir 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.

Constituent	Influent rate to aerated basins, Mg/yr	Outlet concentration, x 10 ³ mg/L	Emis <u>sion rate, Mg/yr</u>		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 hexanold	30.1	1,800	26.2	1.2	28	1.3	16	0.7
2-Ethyl hexyl acrylated	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	Ø.8	2.6	Ø.87	186	62
Benzened	17	16	17	1.4	18	1.5	1,100	94
Toluened	4.7	11	4,7	5.6	5.1	6.1	46Ø	65Ø
Ethyl benzened	11	43	11	2.4	12	2.6	280	60

TABLE F-33. SOURCE TESTING RESULTS^a FOR TSDF SITE 12, AERATED STABLIZATION BASINS

TSDF = Treatment, storage, and disposal facility.

NA = Not available.

^aTwenty-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.

 $^{
m b}$ The mass transfer coefficient is emission flux rate divided by outlet concentration.

^CNo air sampling results were presented for these compounds.

^dAir 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.

 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) 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-34 presents a summary of the source testing results.

F.1.3.2 <u>Site 6</u>.³⁵ 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).

Constituent	Mean emission rate, Mg/yr	Mean soil concentration, x 10 ⁻³ µg/m ³	Emission flux rate, ^b x 10 ⁶ g/m ² •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

TABLE F-34. SOURCE TESTING RESULTS^a FOR TSDF SITE 13, ACTIVE LANDFILL

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

^aAir emissions were sampled with a flux chamber and soil concentrations were determined from samples collected with a thin-wall, brass core sampler.

^bThe emission flux rate is the emission rate converted to grams/second divided by the exposed surface area (19,970 m²) of the landfill.

^CThe NMHC totals do not represent column sums because only major constituents (in terms of relative concentrations) are presented.
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 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 m². 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 m². 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 m². 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 $1,490 \text{ m}^2$. 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 be an elected 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-35 summarizes the source testing results for the inactive landfill. Tables F-36 and F-37 summarize the source testing results for areas 1 and 2, respectively, of the active landfill.

F.1.3.3 <u>Site 14</u>.^{36,37} Site 14 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 14 consists of multiple cells with overall dimensions of 549 by 152 by 4.6 m deep.

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Constituent	Mean emission rate, x 10 ³ Mg/yr	Emission flux rate, ^t x 10 ⁹ g/m ² •s	
Methylene chloride	10	130	
1,1,1-Trichloroethane	5.3	71	
Total NMHC ^C	56	750	

TABLE F-35. SOURCE TESTING RESULTS^a FOR TSDF SITE 6, INACTIVE LANDFILL

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

^aAir emissions were sampled with a flux chamber.

^bThe emission flux rate is the emission rate converted to grams/second divided by the surface area (2,370 m²) of the inactive landfill.

Constituent	Mean emission rate, x 10 ³ Mg/yr	Mean soil concentration, µg/m ³	Emission flux rate, ^b x 10 ⁹ g/m ² •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

TABLE F-36. SOURCE TESTING RESULTS^a FOR TSDF SITE 6, ACTIVE LANDFILL, TEMPORARY STORAGE AREA

TSDF = Treatment, storage, and disposal facility.

ND = Not detected.

NMHC = Nonmethane hydrocarbon.

^aAir emissions were sampled with a flux chamber and soil concentrations were determined from samples collected with a thin-wall, brass core sampler.

^bThe emission flux rate is the emission rate converted to grams/second divided by the surface area (1,470 m²) of the active landfill temporary storage area.

Constituent	Emission rate, x 10 ³ Mg/yr	Soil concentration, µg/m ³	Emission flux rate,b x 10 ⁹ g/m ² •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

TABLE F-37. SOURCE TESTING RESULTS^a FOR TSDF SITE 6, ACTIVE LANDFILL, ACTIVE WORKING AREA

TSDF = Treatment, storage, and disposal facility.

ND = Not detected.

NMHC = Nonmethane hydrocarbon.

^aAir emissions were sampled with a flux chamber and soil concentrations were determined from samples collected with a thin-wall, brass core sampler.

^bThe emission flux rate is the emission rate converted to grams/second divided by the surface area (670 m²) of the active landfill active working area.

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 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-38 presents the source testing results from cell A of the Site 14 landfill.

F.1.3.4 <u>Site 15</u>.^{38,39} Site 15 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:

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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

TABLE F-38. SOURCE TESTING RESULTS^a FOR TSDF SITE 14, ACTIVE LANDFILL, CELL A

TSDF = Treatment, storage, and disposal facility.

ND = Not detected.

NMHC = Nonmethane hydrocarbon.

^aAir emissions were sampled with a flux chamber and soil concentrations were determined from a sample collected in a glass VOA vial.

^bThe emission flux rate is the emission rate converted to grams/second divided by the surface area (185 m²) of cell A.

- 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.

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 $3.3 \times 10^5 \text{ m}^3$. 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 0 is typical of the inactive landfills at Site 15. Landfill 0 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 x 10^{-7} cm/s. Closed landfills at Site 15 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 0 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 0 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 $38,000 \text{ m}^2$.

Canister samples were analyzed offsite using a Varian Model 3700 GC-FID/PID/HECD. Syringe samples were analyzed onsite by GC-FID. Table F-39 presents the results of the canister sample collected from a standpipe in the general organic cell of landfill O. Table F-40 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 <u>Site 7</u>.40,41,42 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

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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

TABLE F-39. SOURCE TESTING RESULTS^a FOR TSDF SITE 15, INACTIVE LANDFILL O

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

^aThis table presents the results of the analysis of a single canister sample collected from a standpipe in the general organic 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	

TABLE F-40. SOURCE TESTING RESULTS^a FOR TSDF SITE 15, ACTIVE LANDFILL P, FLAMMABLE WASTE CELL

TSDF = Treatment, storage, and disposal facility.

NMHC = Nonmethane hydrocarbon.

^aAir emissions were sampled with a flux chamber. One air canister sample was collected from the flammable waste cell. No soil samples were collected.

^bThe emission flux rate is the emission rate converted to grams/second divided by the surface area (7,600 m²) of the flammable waste cell.

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 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 $6,900 \text{ m}^3/\text{mo}$.

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 semitrailers 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 m³ 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 $5.1-\mu$ m PVC liner, 0.46 m of uncompacted clay, and 15.2 cm of topsoil/sod. The design permeability of this cap is 1 x 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.

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% neutral- ized salts
No. 2	10	Pseudo metals	Antimony, arsenic, beryl- lium, bismuth, phosphorus, selenium, tellenium	Soils with calcium carbonate waste solids
No. 3	25	General wastes	Nonhalogenated aromatics, hydroxyl and amine deriva- tives, acid aldehydes, ketones, flashpoint greater than 54 °C	65% soil 35% neutral- ized salts
No. 4	15	Halogenated wastes	Controlled organics with flashpoint greater than 54 °C not suitable for fuel, PCB-contaminated soils	65% soil 35% neutral- ized 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% neutral- ized salts

TABLE F-41. DESCRIPTION^a OF TSDF SITE 7, DESCRIPTION OF SUBCELLS IN ACTIVE LANDFILL B⁴³

TSDF = Treatment, storage, and disposal facility. PCB = Polychlorinated biphenyls.

^aCharacteristics of the active landfill B subcells at the time source testing was conducted.

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-42 lists the purgeable organics (as measured by EPA Method No. 624) reported by Site 7 in the leachate from chemical landfill A.

The major compounds found were methylene chloride, trans-1,2-dichloroethene, chloroform, 1,2-dichloroethane, trichloroethane, benzene, 1,1,2,2tetra-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 m² and of the general organic cell 4,200 m².

No emissions through the cap of inactive landfill A were detected using the flux chamber technique. The canister samples were taken from two

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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

TABLE F-42. PURGEABLE ORGANICS^a REPORTED IN LEACHATE FROM CHEMICAL LANDFILL A AT TSDF SITE 5⁴⁴

TSDF = Treatment, storage, and disposal facility. $^{a}Measured$ by EPA Method 624.

vents and were analyzed offsite using Varian Model 3700 GC-FID/PID/HECD. Table F-43 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-44 and F-45 present the results of the analyses for the flammable and general organic cells, respectively.

F.1.4 Land Treatment

F.1.4.1 Site 16. 45 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 CO₂ 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 technique⁴⁶ (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

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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

TABLE F-43. SOURCE TESTING RESULTS^a FOR TSDF SITE 7, INACTIVE LANDFILL A

TSDF = Treatment, storage, and disposal facility.

ND = Not detected.

NMHC = Nonmethane hydrocarbon.

^aThis 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.

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

TABLE F-44. SOURCE TESTING RESULTS^a FOR TSDF SITE.7, ACTIVE LANDFILL B, FLAMMABLE WASTE CELL

TSDF = Treatment, storage, and disposal facility.

ND = Not detected.

NMHC = Nonmethane hydrocarbon.

^aAir emissions were sampled with a flux chamber and soil concentrations were determined from samples collected in glass volatile organic analysis vials.

^bThe emission flux rate is the emission rate converted to grams/second divided by the surface area (2,100 m²) of the flammable 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

TABLE F-45. SOURCE TESTING RESULTS^a FOR TSDF SITE 7, ACTIVE LANDFILL B, GENERAL ORGANIC WASTE CELL

TSDF = Treatment, storage, and disposal facility.

ND = Not detected.

NMHC = Nonmethane hydrocarbon.

^aAir emissions were sampled with a flux chamber and soil concentrations were determined from samples collected in glass volatile organic analysis vials.

^bThe emission flux rate is the emission rate converted to grams/second divided by the surface area (4,200 m²) of the general organic cell.

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-46. Table F-47 presents the cumulative emissions over the test period and the weight fraction of applied oil emitted over the test period.

F.1.4.2 <u>Site 17</u>.⁴⁷ 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 landtreated 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.

	Perc	ent composition	1, wt %		
		Test 2		Test 3	
Waste constituent	Test 1 API separator sludge	API separator sludge	Centrifuged waste ^b	TFE- processed waste ^C	TFE- processed waste ^d
0i1	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

TABLE F-46. WASTE ANALYSES^a OF PETROLEUM REFINERY SLUDGES USED IN LAND TREATMENT TESTS AT SITE 16

Note: Test numbers do not correspond to those used in the test report.

VO = Volatile organic.

TFE = Thin film evaporator.

NA = Not analyzed.

^aThe 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.

^bAPI separator sludge, treated to simulate a centrifuge and drying operation, was used.

 $^{\rm C}{\rm Oily}$ waste processed by TFE under conditions of high feed rate and low temperature.

^dOily waste processed by TFE under conditions of low feed rate and high temperature.

		Test	Emissions				
Test	No.	duration, d	Cumulative, kg ^b	Wt % of applied oil ^C			
Test 1, sludge	API separator	69	0.38	40			
Test 2, sludge	API separator	22	0.06	11			
Test 2, waste ^d	centrifuged	22	0.005	1			
Test 3, waste ^e	TFE-processed	26	0.005	1			
Test 3, waste ^f	TFE-processed	26	0.01	2			

TABLE F-47. MEASURED AIR EMISSIONS^a FROM LAND TREATMENT LABORATORY SIMULATION AT SITE 16

Note: Test numbers do not correspond to those used in the test report.

^aLaboratory simulation of land treatment operation using subsurface injection.

^bAir samples analyzed for hydrocarbons by gas chromatograph-flame ionization detector and for CO₂ by gas chromatograph-thermal conductivity detector.

^CWeight fraction of applied oil emitted over test period.

dAPI separator sludge, centrifuged and dried before testing.

^eOily waste processed by TFE under conditions of high feed rate and low temperature.

^fOily waste processed by TFE under conditions of low feed rate and high temperature.

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 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-48 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-49 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 <u>Site 18</u>.⁴⁸ 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.

Waste	Percent com	Percent composition, wt %			
constituent	Run 1 ^b	Run 2 ^C			
Oil	29.5	21.3			
Water	65.0	69.7			
Solids	5.5	9.0			

TABLE F-48. WASTE ANALYSES^a OF PETROLEUM REFINERY SLUDGES USED IN LAND TREATMENT LABORATORY SIMULATION AT SITE 17

^aThe oil, water, and solids content was determined using the modified oxygen drying technique.

^bAmerican Petroleum Institute separator sludge was used.,

^CInduced air flotation float was used.

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Test run/ soil box ^a	Test duration, h	Oil loading, kg oil/m ^{2b}	Total VO emissions at 740 h, ^c kg	Percent of total oil applied emitted	Percent of total VO applied emitted
Run 1d	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

TABLE F-49. TOTAL VO EMISSIONS AT 740 HOURS AFTER APPLICATION OF PETROLEUM REFINERY SLUDGES TO LAND TREATMENT SOIL BOXES, SITE 17

VO = Volatile organics.

NA = Not applicable.

^aFor Run 1, American Petroleum Institute (API) separator sludge was surface-applied. For Run 2, induced air flotation sludge was surfaceapplied.

^bAs measured using the modified oven drying technique (MODT).

^CBased 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.)

^dSludge 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.

^eAverage MODT results used rather than MODT results for Box 4.

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.

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-50.

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-50 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-51 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 <u>Site 19</u>.⁵⁰ In 1984, field tests of land treatment emissions were conducted at Site 19, 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.

TABLE F-50. WASTE ANALYSIS, CONCENTRATION OF VOLATILE ORGANIC CONSTITUENTS IN PETROLEUM REFINERY SLUDGES^a APPLIED IN LAND TREATMENT FIELD EXPERIMENTS AT TSDF SITE 18⁴⁹

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.

^aWaste was a combination of American Petroleum Institute separator sludge and dissolved air flotation sludge.

^bConstituent analysis done using gas chromatographflame ionization detector.

^CEach concentration is the average of 10 waste samples.



Figure F-5. Measured emission flux for one plot over one test period at Site 18.

						Cumuta	tive emiss	ionsb						
Test	Benz	enec	Ţolu	ene	Ethylbe	nzene ^C	p-Xyl	ene	m−Xyl	ene	o-Xyl	ene	Naphth	alene
location	µ/g/cm_2	wt %	$\mu_{g/cm}^2$	wt %	µ/g/cm ²	wt %	#g/cm ²	wt %	,µ/g/cm ²	wt %	$\mu_{g/cm}^2$	wt %	$\mu_{g/cm}^2$	wt %
Α	272	81	349	41	58	195	7	16	96	、 39	21	28	2	1
8	300	110	454	66	96	402	8	21	164	83	23	38	2	2
Cq	188	39	210	17	59	140	16	25	87	25	19	17	3	1
D	456	141	7Ø3	86	101	353	24	55	185	79	38	52	3	2
E	382	106	576	63	1ø9	345	21	43	136	52	32	39	2	1
F	325	84	465	47	72	2Ø8	7	13	78	28	21	24	2	1
										- · ·				

TABLE F-51. RESULTS OF PETROLEUM REFINERY SLUDGE LAND TREATMENT FIELD EXPERIMENTS® AT TSDF SITE 18

TSDF = Treatment, storage, and disposal facility.

^aFlux 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.

^bTest duration was approximately 8 d.

^CIn 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.

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 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/m² (50 bbl/1/8 acre).

The objectives of the test program at the Site 19 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 1.40×10^4 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 413.1.⁵¹ 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-52 shows estimated total cumulative emissions of selected individual compounds and total VO over the entire test schedule.

F.1.4.5 <u>Site 14</u>.⁵³ From November 14 through November 17, 1983, field tests of land treatment emissions were conducted at Site 14, 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



Figure F-6. Measured VO emission flux for first 12 days at Site 19.

	Cumulative emissions, ^b wt % of applied material ^C				
Constituenta	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			

TABLE F-52. ESTIMATED CUMULATIVE EMISSIONS OF SELECTED ORGANIC CONSTITUENTS AND TOTAL VO FROM CRUDE OIL REFINERY WASTE LAND TREATMENT FIELD TESTS AT TSDF SITE 19⁵²

TSDF - Treatment, storage, and disposal facility.

VO = Volatile organics.

^aAir samples for chemical specification were collected in canisters using a flux chamber.

^bTest duration was 5 weeks.

^CWaste 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.

^dDetermined 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 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.

testing period. The calculated application rate was $34,720 \text{ g/m}^2$; 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-53 lists waste and land application characteristics.

The objective of the test program at the Site 14 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-54 shows cumulative measured total VO emissions and cumulative benzene emissions.

F.1.4.6 <u>Site 20</u>.⁵⁶ 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:

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) Second tilling (h)	19 47				

TABLE F-53. TSDF SITE 14 WASTE AND LAND TREATMENT FACILITY^a CHARACTERISTICS⁵⁴

TSDF = Treatment, storage, and disposal facility.

^aSite 14 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 14.

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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)

TABLE F-54. MEASURED CUMULATIVE LAND TREATMENT EMISSIONS^a AT TSDF SITE 14⁵⁵

TSDF = Treatment, storage, and disposal facility. VO = Volatile organics.

^aAir emissions sampled with a flux chamber.

^bTest 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.

^CDetermined using purge-and-trap technique and analyzed using a Varian Model 3700 gas chromatograph-flame ionization detector/photoionization detector/Hall electrolytic conductivity detector.

- Obtain detailed information and samples of sludges and soils from refineries that use land treatment to dispose of oily sludges
- 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 <u>Agriculture</u> <u>Handbook No. 60</u>),⁵⁷ specific gravity (ASTM D854-54),⁵⁸ moisture content (using weight loss after 16 h at 50 °C), particle size distribution (ASTM D422),⁵⁹ soil classification (ASTM D2487),⁶⁰ oil and grease content (EPA Method No. 413.1), organic carbon by heating (ASTM D2974),⁶¹ 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),⁶² 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 m². 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 study⁶³ 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-55.



Figure F-8. Average measured emission flux at Site 20.

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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

TABLE F-55. AVERAGE CUMULATIVE EMISSIONS FROM A LABORATORY SIMULATION OF PETROLEUM REFINERY WASTE LAND TREATMENT^a AT SITE 20⁶⁴

^aIndependent research Laboratory simulation of land treatment activities. Total hydrocarbon emissions monitored using a Byron 401 analyzer.

^bSludge type (surface applied):

^CTest duration for each run was 8 h.

F.1.4.7 <u>Site 21</u>.⁶⁵ In 1979, field tests were conducted at a land treatment facility at Site 21, 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 21 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/m² (760 bbl/acre) and contained 1.7 kg/m² (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/m² (900 bbl/acre) and contained 3.2 kg/m² (28,300 lb/acre [8.1 weight percent]) organic fraction. Table F-56 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.

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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		
0il (wt %)	8.1	5.2
Water	72.1	85.2
Solids	19.8	9.6

TABLE F-56. WASTE CHARACTERISTICS AND APPLICATION RATES FOR FIELD EXPERIMENTS ON PETROLEUM REFINERY WASTE LAND TREATMENT, TSDF SITE 2166

TSDF = Treatment, storage, and disposal facility. API = American Petroleum Institute.

^aAnalyzed 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-57 summarizes the Site 21 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 21.

F.1.5 Transfer, Storage, and Handling Operations

F.1.5.1 <u>Site 6.68</u> 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

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	7	25.8/619	10.9
sludgen	8	5.1/122	3.3
	9	21.7/520	10.4

TABLE F-57. FRACTION OF APPLIED OIL EMITTED BY LAND TREATMENT TEST AT TSDF SITE 2167

TSDF = Treatment, storage, and disposal facility. API = American Petroleum Institute.

^aAir emissions sampled with flux chamber. Waste was surface-applied. ^bWeathered 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 21.

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-m³ 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-58 presents the results of the survey.

Sampling	Concentration of	
location	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

TABLE F-58. SUMMARY OF DRUM STORAGE AND HANDLING AREA SURVEY OF AMBIENT HYDROCARBON CONCENTRATIONS,^a SITE 6⁶⁹

THC Total hydrocarbon.

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PCB = Polychlorinated biphenyl.

^aAmbient hydrocarbon measurements were made in the immediate vicinity of the storage areas with a portable organic vapor analyzer.

F.1.5.2 <u>Site 22</u>. 70,71 Site 22 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 22 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 22. 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-59.

Storage tanks at Site 22 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 <u>Site 7</u>.⁷³ 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 m³/s at 0.245 standard pressure (S.P.). Makeup air enters through two vents at the end of the building opposite the

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	Distance of	Concent THC	ration of , ppm
Sampling location	drums, m	OVA	PID
Upper drum storage area			
East side East side South side West side North side	0.3 6.1 2.4 2.4 1.5	60 7 5 5-7 10-20	9 0.5 0.1 0.1 5-10
Lower drum storage area			
East side South side West side North side	2.4 2.4 2.4 2.4	10-20 20-30 5 7	0-2 5-15 0.1 0-0.2

TABLE F-59. RESULTS OF EMISSION SURVEY^a AT DRUM STORAGE AREA, SITE 22⁷²

THC = Total hydrocarbon.

OVA = Organic vapor analyzer.

PID = Photoionization detector.

^aReal-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 m³/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-m³ steel drums, 2 to 5 percent overpack, and 1 percent 0.11-m³ 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-60 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.

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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

TABLE F-60. SOURCE TESTING RESULTS^a FOR TSDF SITE 7 DRUM STORAGE BUILDING⁷⁴

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

^aVent 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.

^bThe 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 <u>Air-Supported Structures--Site 11</u>.⁷⁵ Section F.1.2.3 contains a description of the testing program conducted during the week of August 13 through 19, 1984, at the Site 11 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 m³/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 m³/s. F.2.2 Add-on Control Devices

F.2.2.1 Gas-Phase Carbon Adsorption.

F.2.2.1.1 <u>Site 23</u>.⁷⁶ A test program was conducted for 4 days during May 1985 on the air-stripping system used to treat leachate at Site 23. Site 23 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 $4.8 \text{ m}^3/\text{min}$, giving the highest air:water ratio observed during testing. Table F-61 presents the source testing results.

F.2.2.1.2 <u>Site 11</u>.⁷⁷ Section F.1.2.3 contains a description of the WWT system at Site 11, 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-m³ (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-62 presents the carbon adsorption fixed-bed system removal efficiency for specific species. Table F-63 presents the neutralizer vent carbon drum removal efficiency results.

Constituent	Exhaust <u>air str</u> Mass flow rate, x 10 ³ kg/h	from ipper Conc., ng/L	Exhaust <u>carbon a</u> Mass flow rate, x 10 ⁶ kg/h	from <u>dsorber</u> Conc., ng/L	Carbon adsorber system organic removal efficiency, wt. %
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

TABLE F-61. SOURCE TESTING RESULTS^a FOR TSDF SITE 23, AIR STRIPPER EMISSIONS WITH GAS-PHASE, FIXED-BED CARBON ADSORPTION SYSTEM APPLIED

TSDF = Treatment, storage, and disposal facility.

NA = Not available.

VO = Volatile organics.

^aThis tables demonstrates the effectiveness of activated carbon as an adsorbent for VO in gas streams.

^bConcentration reported for all isomers of dichlorobenzene, not just 1,2-dichlorobenzene.

^CConstituent concentration below detection limit.

^dIncludes 4-methyl-2-pentanone, chlorobenzene, tetrachloroethylene, and dichlorocyclohexane isomers.

^eIncludes all speciated organics.

TABLE F-62. SOURCE TESTING RESULTS^a FOR TSDF SITE 11, AERATED LAGOON EMISSIONS WITH GAS-PHASE CARBON ADSORPTION FIXED-BED SYSTEM APPLIED⁷⁸

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Gas-phase concentration, ppmv													
Date	Location	MeCl ₂	C2H4CI2	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	6Ø7
18-Aug-84	Outlet	2.1	355	Ø.Ø	24.8	54.1	8.8	Ø.1	34.0	167	89.8	4Ø9	698
Removal e	ff. ^b (%)	51.2	-47.9	NA	-17.0	41.3	-2,100	91.7	58.3	-9.2	23.2	-23.6	-15.Ø
17-Aug-84	In¦et	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	Ø.8	25.9	49.8	32.2	251	334
Removal e	ff.t (%)	-5.0	-Ø.5	NA	12.3	-31.6	-Ø.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	Ø.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 e	ff. ^t (%)	0.0	-34.3	NA	-236	-284	-83.3	60.0	1.8	-25.Ø	-245	-32.0	-42.8
17-Jul-84	Inlet	0.0	770	0.0	2.4	181	76.8	NA	NA	45.6	3Ø3	848	1,360
17-Jui-84	Outlet	0.0	770	0.0	2.6	119	112	NA	NA	5Ø.3	217	1,070	1,480
Removal e	ff, ^b (%)	NA	0.0	NA	-8.3	34.3	-45.8	NA	NA	-10.3	28.4	-26.2	-8.8
	······	· ·· ·							····	-			-

= Treatment, storage, and disposal facility. TSDF = 1,2-Dichloroethane. C2H4C12 DCBZ = Dichtorobenzene. MeC12 = Methylene chloride. NA = Not applicable. NMHC = Nonmethane hydrocarbon. CBZ = Chlorobenzene. Paraffins = Primarily C7 and C8 compounds. NMHC = Nonmethane hydrocarbon.

^aThis 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.

^bThe 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.

					G	as-phase	conce	ntrati	on, ppmv				
Date	Location	MeCl	C ₂ H ₄ Cl ₂	Dioxane	Benzene	Toluene	CBZ	DCBZ	Chloroform	Paraffin	Aromatic	Halogen	NMHC
19-Aug-84 19-Aug-84	Inlet Outlet	Ø.Ø 2.6	17.9 Ø.Ø	Ø.Ø Ø.Ø	12.4 Ø.Ø	12.4 Ø.Ø	Ø.5 Ø.Ø	Ø.Ø Ø.Ø	Ø.1 Ø.Ø	8.7 Ø.8	25.1 Ø.2	19.3 23.5	53.1 24.7
Removal ef	f. ^b (%)	NA	100	NA	100	100	100	NA	100	9Ø.8	99.2	-21.8	53.5

TABLE F-63.	SOURCE	TESTING	RESULTS ^a	FOR TS	SDF SITE	11,	NEUTRAL	IZER	TANK	EMISSIONS	WITH A	A
		GAS-PH	ASE CARB	ON DRU	APPLIE	D, TS	DF SITE	1179	1			

TSDF = Treatment, storage, and disposal facility.

DCBZ = Dichlorobenzene.

NMHC = Nonmethane hydrocarbon.

NA = Not applicable.

CBZ = Chlorobenzene.

Paraffins = Primarily C7 and C8 compounds.

^aThis table demonstrates the variation in removal efficiency for gas-phase carbon adsorption of different specific compounds and chemical classes.

^bThe test report does not explain the negative removal efficiency for halogens.

As the results in Table F-62 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 5.80 Tests were conducted on November 20, 1985, to evaluate the effectiveness of liquidphase 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 steamstripper 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 pHadjusted 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-64 presents the source testing results for the TSDF Site 5 liquid-phase carbon adsorption system.

F.2.2.3 <u>Condensation</u>.

F.2.2.3.1 <u>Site 24.81</u> 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 24. The system consisted of a watercooled 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-65 presents the source testing results including mass flow rates of four specific volatile organics into and out of the Site 24 primary condenser. Condenser organic removal efficiencies are reported

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	Influe carbon a	nt to dsorber_	Efflu from ca adsor	Carbon adsorber		
Constituent	Mass flow rate, kg/h	Conc., ppmw	Mass flow rate, kg/h	Conc., ppmw	removal efficiency,b wt %	
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	31,500d	NA	31,500 ^d	NA	NA	

TABLE F-64. SOURCE TESTING RESULTS^a FOR TSDF SITE 5, STEAM STRIPPER WASTEWATER TREATED BY A LIQUID-PHASE CARBON ADSORPTION SYSTEM

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

^aThis table presents the effectiveness of carbon adsorption as a wastewater treatment technology for dilute nitroaromatic-containing streams.

^bValues represent minimum removal efficiencies resulting from constituent concentrations below analytical detection limits.

^CCalculated as the total of the three detected compounds.

^dBalance after accounting for three quantitated organics.

				Condenser
	Ma	organic removal efficiency		
Constituent	Vapor in ^b	Liquid out ^C	Vapor out	د ا ا ا د ا د ا د ا د ا د ا روانه کې
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 VOd	13,700	12,400	1,230	90.9

TABLE F-65. SOURCE TESTING RESULTS^a FOR TSDF SITE 24, STEAM STRIPPER OVERHEAD TREATED BY PRIMARY WATER-COOLED CONDENSER⁸²

TSDF = Treatment, storage, and disposal facility.

VO = Volatile organics.

^aThis table presents mass flow rates by constituent into and out of the primary water-cooled condenser associated with the steam stripper at TSDF Site 24. Under operating conditions at the time of the test, no additional removal was observed in the secondary condenser.

^bFrom mass balance around stripper.

^CBy difference between inlet and outlet vapor flows.

dTotal of four quantified organics.

based on effluent data. The condenser influent data presented are based on a mass balance.

F.2.2.3.2 <u>Site 25</u>.83 Tests were performed on July 22 and 23, 1986, to evaluate the performance of the condenser system used to recover V0 steam stripped from wastewater at the Site 25 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-66 presents the source testing results for the Site 25 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

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.

^aThis table describes the TSDF Site 25 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.

^bBased 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 (1,2dichloroethane). 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 <u>Site 24</u>.⁸⁵ Tests were performed on the Site 24 steam stripper on September 24 and 25, 1986. The Site 24 plant produces onecarbon chlorinated solvents such as methylene chloride, chloroform, and 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 24 wastewater enters one of two decanters (each approximately 76 m³) 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 m³). 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 m³) 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 24 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 volatile organics 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 601.⁸⁶ Method 601 is a purgeand-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 24 steam stripper are given in Table F-67.

F.2.3.1.2 <u>Site 25</u>.⁸⁷ Tests were performed on the Site 25 steam stripper on July 22 and 23, 1986. The Site 25 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 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 25 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

	Influent to_stripper		Effluent from stripper		Steam-stripper					
	Mass flow	Conc., ppmw	Mass flow rate, g/h		Overhead		organic removal	Vent		
Constituent	rate, g/h			Conc., ppmw	Flow, kg/h	Conc., ppmw	efficiency, ^a wt %	emissions,b Mg/yr		
Chloromethane	79.6	32.6	<0.014	<0.005	NA	NA	>99.98	Ø.51		
Methylene chloride	10,800	4,490	<Ø.Ø28	<0.011	9.25	787,000	>99.999	39		
Chloroform	3,090	1,270	<0.017	<0.006	2.5Ø	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		

TABLE F-67. SOURCE TESTING RESULTS FOR TSDF SITE 24, STEAM STRIPPER

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

^aBased on fraction of influent mass not accounted for in stripper bottoms.

^bTotal emissions from steam stripper, solids decanter, and storage tank, based on operation of 50 wk/yr.

(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-68 presents the source testing results including average stream mass flow and composition data for each stream entering and leaving the Site 25 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-68 but are not used to calculate removal efficiencies. This is done because of the need to see the actual amount of organic removed from the wastewater and because of the incompleteness of the condensate data.

F.2.3.1.3 <u>Site 5</u>.88 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 m³ of 2.5-cm diameter stainless steel rings. The steam stripper operates with a gas-to-liquid ratio ranging from 55 m³/m³ at the bottom of the column to 24 m³/m³ 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

			Overhead condensate ^a								
	Influent to stripper		Effluent from stripper Mass flow		Aqueous		Organic		Steam- stripper organic	Condenser	
	Mass flow		rate,		Mass flow	Conc.,	Mass flow	Conc.,	removal	vent	
	rate,	Conc.,	× 10 ⁶	Conc.,	rate,	× 10 ⁻³	rate,	× 10 ⁻³	efficiency	emissions,	
Constituent	kg/h	ppmw	kg/h	ppmw	kg/h	ppmw	kg/h	ppmw	wt %	Mg/yr	
1,2-Dichloroethane	270	5,600	4,900	0.097	110	95 ^b	190	87Ø ^b	99.998	11	
Chloroform	13	270	480,000	9.6	11	9.1 ^b	15	7Ø ^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	NĂ	>97.0	NA	
Chloroethane	Ø.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	Ø.23	4.7	<500	<0.01 ^c	NA	NA	NA	NA	>99.8	0.98	
1,2-Dichioroethene	Ø.44	8.9	<500	<0.01 ^C	NA	NA	NA	NA	>99.9	Ø.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	Ø.37	7.5	<500	<0.01 ^c	NA	NA	NA	NA	>99.9	NA	
Trichloroethene	Ø.24	4.8	<500	<0.01 ^C	NA	NA	NA	NA	>99.8	NA	
Vinyl chloride	Ø.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	94Ø	>99.8	20	
								· · · · · · · · ·			

TABLE F-68. SOURCE TESTING RESULTS FOR TSDF SITE 25, STEAM STRIPPER

TSDF = Treatment, storage, and disposal facility.

NA = Not analyzed for this constituent.

VO = Volatile organics.

^aNot used for calculation of removal efficiencies because of need to determine actual organic removed and incompleteness of condensate analyses.

^bOnly 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.

CAll concentrations were below detection limit.

^dCalculated as sum of quantified organic compounds.

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-69 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.2.3.1.4 <u>Site 26</u>.⁸⁹ Source testing was conducted from December 3 through 5, 1984, on the Site 26 steam stripper. Site 26 is engaged in the reclamation of organic solvents for recycle and sale. The live steamstripping process is used for organic solvent reclamation. This system is located inside a building that also contains three 3.8-m³ waste solvent storage tanks and three 3.8-m³ product storage tanks. The building also is used for drum storage. There are five 38-m³ outside storage tanks that are used primarily for contaminated solvent and residue storage. An oil/gasfired boiler system is used for process steam generation. An analytical laboratory is maintained in the building that houses company offices.

~											
		Effluent				Overhead_condensate					
Constituent [.]	Influent to stripper		from stripper		Aqueous		Organic		Steam-	D3	
	Mass flow rate, kg/h	Conc., ppmw	Mass flow rate, kg/h	Conc., ppmw	Mass flow rate, kg/h	Солс., рртж	Mass flow rate, kg/h	Conc., × 10 ⁻³ ppmw	stripper organic removal, wt %	emissions, × 10 ³ Mg/yr	
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	Ø.868	2,000	16.6	1,080	92.0	(3.3	
4-Nitrotoluene Total VO ^b	1.53	51 63Ø	Ø.139 1.51	4,4	Ø.019 Ø.868	45 2,000	1.49	97 1,080	90.9 92.0	د د د	

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TABLE F-69. SOURCE TESTING RESULTS FOR TSDF SITE 5, STEAM STRIPPER

TSDF = Treatment, storage, and disposal. VO = Volatile organics.

^aCondenser vent emissions.

^bTotal of three quantified organics.
The contaminated organics processed by Site 26 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 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 m³ 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 26 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-trichloro-ethane/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 26 steam stripper source testing results are presented in Table F-70. 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.2.3.1.5 <u>Site 27</u>.⁹⁰ Tests were performed August 18 and 19, 1984, on the Site 27 steam stripper. The steam stripper at Site 27 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

					0	erhead cond	Steam			
	Init strippe	ial r_charge 、	Final st resi	due	Aque	ous	0rg	anic	stripper organic removal efficiency, wt %	Process ^d air emissions, (10 ³ Mg/yr
Constituent	Mass, kg	Conc.,t ppmw	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw		
Batch 1										
Acetone	0.049	39	<0.008 6	<6	0.087	350	<0.3	<1,000	91	NA
Isopropanol	1.2	96Ø	<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	Ø.2	1,100	(0.3	<1,000	87	4.2
Tetrachloroethene	Ø.36	290	<i><0.0</i> 28	<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	Ø.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	Ø.18	320	<Ø.0038	<7	Ø.22	1,200	Ø.6	14,000	99	NA
Acetone	Ø.16	290	<0.0032	Χ 6	0.20	1,100	<0.004	<1,000	99	NA
Ethy! 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

TABLE F-70. SOURCE TESTING RESULTS^a FOR TSDF SITE 26, STEAM STRIPPER

See notes at end of table.

(continued)

TABLE F-70 (continued)

					0.4	erhead cond	Steam			
	Initial strippør charge		Final stripper residue		Aqueous		Organic		stripper organic	Processd
Constituent	Mass, kg	Conc.,b ppmw	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw	efficiency wt %	emissions, x 10 ³ Mg/yr
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	Ø.78	2,200	0.080	23Ø	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	NĂ
Xylene	0.001	49	0.042	120	0.045	320	Ø.86	270,000	NA	NĂ
Total VO®	3.489	9,700h	0.14	390	4.6	34,000	Ø.99	310,000	96	NA
						C				

TSDF = Treatment, storage, and disposal facility.

NA = Not available.

VO = Volatile organics.

^aThis table describes the mass balance around the steam stripper at Site 26 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.

^bConcentrations given for liquid charged to batch stripper.

^CNot 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.

dCondenser vent emissions based on 24 h/d, 5 d/wk operation.

^eTotal of compounds accounted for.

^fAccidental inclusion of an unknown xylene/aromatic mixture. Estimated initial masses from final results.

9Below amount expected due to unmixed sample collected.

^hEstimated from later concentration.

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.

The objective of the field test of the steam-stripping process at Site 27 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).⁹¹ The VO in the liquid samples were analyzed by GC-MS (Method 8240).⁹² Material and energy balances and stream flow and concentration data were used to characterize all process streams around the steam stripper. Table F-71 presents the source testing results.

F.2.3.2 Air Stripping.

F.2.3.2.1 <u>Site 23</u>.⁹³ A test program was conducted for 4 days during May 1985 on the Site 23 air stripping system. Site 23 is an NPL Superfund site currently managed by EPA under CERCLA. It is a 1.6-ha abandoned waste

Constituent	Influent to stripper		Effluent <u>from stripper</u> Mass flow		Overhead <u>condensate^a</u> Mass flow		Steam stripper organic	Process	
	Mass flow rate, kg/h	Conc., mg/kg	rate, x 10 ⁶ kg/h	Conc., mg/kg	rate, x 10 ³ , kg/h	Conc., mg/kg	removal efficiency, wt %	air emissions, ^b x 10 ³ Mg/yr	
Methylene chloride	4.6	3,900°	789	Ø.Ø66	88	5,200	>99.99	1,400	
Chloroform	Ø.Ø67	57	6,000	5.1	19	1,100	91	13	
Carbon tetrachloride	d	d	<29Ø 0	<0.250f	<0.043	<2.5	NA	4.7	
Total VO	4.7	3,900	6,000	5.2	107	6,300	99. 8	1,400	

TABLE F-71. SOURCE TESTING RESULTS FOR TSDF SITE 27, STEAM STRIPPER

TSDF = Treatment, storage, and disposal facility.

NA = Not available.

VO = Volatile organics.

^aNot used for calculation of removal efficiencies because of desire to see actual removal from waste stream and to remove any background interference effects.

bProduct receiver tank vent flow rate equals 1 L/s.

^cCalculated from average concentrations and average influent flow rate.

dTwelve of thirteen analyses below reliable detection limit.

^eSome concentrations observed were below the detection limit; results presented are averages over 13 samples with samples below detection limit averaged as zero.

^fAll analyses below reliable detection limit.

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 counter-currently 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 Section F.2.2.1.1. The water effluent from the stripper column directly enters a creek. The VO stripped from the leachate are disposed of with the spent carbon.

The 32.6-cm inside diameter column contains 6.7 m of 2.54-cm super intalox polypropylene saddles and/or 2.54-cm polyethylene Pall rings as the packing material. The system is designed to operate automatically with the air blower operating continuously and the water pump cycling on and off, depending on the volume of leachate available in the collection tank. The pump provides a maximum water feed rate of about 8,200 kg/h but can be throttled down to 1,100 kg/h. Water is generally fed at the maximum pump rate, and, as noted during system testing, this causes the pump to operate approximately 35 percent of the time. The air blower is designed to deliver 0.12 m³/s, but rates measured at the air intake port were less than this and depended on the water feed rate. At a water feed rate of 1,140 kg/h, the measured air rate at the intake port was $0.08 \text{ m}^3/\text{s}$. When the water feed rate was increased to 8,200 kg/h, the air rate at the intake port decreased to less than $0.028 \text{ m}^3/\text{s}$ although the air flow remained essentially constant near the blower for the two different water rates. This is probably because the higher pressure drop at the higher liquid flow rate and equipment leaks allowed outside air to enter the system. The air leaving the column is blown through four 0.21-m³ canisters of granularactivated carbon arranged in parallel. The carbon is replaced every month.

The objectives of the field tests on the air stripper at Site 23 were to:

- Assess the condition and current performance of the existing air-stripping system
- Evaluate treatability of leachate by air stripping
- Determine optimum contaminant removal efficiency attainable at the existing air-stripper system.

Influent and effluent water samples as well as air samples were taken at a variety of water and air flow rates. When the pump cycled on and off during testing, the samples were taken as late as possible during the pumping cycle to ensure that the system was operating close to equilibrium conditions. No information was documented regarding 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.

The air stripper VO removal efficiency was determined at a variety of air:water ratios. The water feed rate was varied from 8,200 kg/h to 1,100 kg/h, and, as noted before, this caused the air flow rate to change. The VO removal efficiency was determined at several intermediate water rates giving a range of air:water ratios from which to characterize the performance of the air stripper. Material balances and stream flow and concentration data were used to characterize the process streams around the air-stripper system.

Table F-72 presents the Site 23 air stripper source testing results under test conditions yielding the highest VO removal from water. This was obtained when the influent water rate was throttled down to 1,140 kg/h and the air flow correspondingly increased to $0.08 \text{ m}^3/\text{s}$, giving the highest air:water ratios observed during testing. Table F-73 presents the source testing results under Site 23 air stripper standard operating conditions at the time of the test, where the water flow rate was 8,200 kg/h, and the air inlet rate was unknown but expected to be less than $0.028 \text{ m}^3/\text{s}$. These conditions represented the lowest air:water ratio at which the column operated and yielded the lowest VO removal efficiency.

F.2.3.3 Thin-Film Evaporation.

F.2.3.3.1 <u>Site 28.94</u> The use and effectiveness of a thin-film evaporator (TFE) on petroleum refinery sludges were tested. A pilot-scale

		Wat	er		Ai	ra			
	Influent to stripper		Efflue from str	Effluent from stripper		ent ripper	Air stripper		
	Mass flow rate, x 10 ⁶	Conc.,	Mass flow rate, x 10 ⁶	v Conc.,	Mass flo rate, x 10 ⁶ ,	Conc.,	organic removal efficiency,	Process air emissions, ^b	
Constituent	kg/h	µ/g/L	kg/h	<i>µ</i> g/L	kg/h	ng/L	wt %	x 10 ⁶ Mg/yr	
1,2,3-Trichloropropane ^C	34,000	30,000	<57Ø	<500d	13,000	44,000	>98	<1.3	
(o,m)-Xylene ^d	15,000	13,000	<57Ø	<500d	5,200	18,000	>96	23	
p-Xylene ^d	4,600	4,000	<57Ø	<500d	1,700	6,000	>88	15	
Toluene	240	210	<57Ø	<500d	2,800	9,800	NA	14	
Aniline	120	102	55	48	NA	NA	63	NA	
Phenol	120	109	32	28	NA	NA	>53	NA	
2-Methylphenol	60	53	18	16	NA	NA	70	NA	
4-Methylphenol	22	19	<11	<10d	NA	NA	>53	NA	
Ethylbenzene	46	40	< 57Ø	<500d	75Ø	2,600	NA	3.8	
1,2-Dichlorobenzene	40	35	<11	<10d	97	34Ø ^e	>71	1.2	
1,2,4-Trichlorobenzene	35	31	<11	<1Ø ^d	NA	NA	>68	NA	
Other VO	62	54	43	38	48Ø	1,700	3Ø	5.1	
Total VO	54,000	47,700	15Ø	1,400	24,000	82,400	>99	64	

TABLE F-72. SOURCE TESTING RESULTS FOR TEST YIELDING HIGHEST VO REMOVAL PERCENTAGE AT TSDF SITE 23, AIR STRIPPER

TSDF = Treatment, storage, and disposal facility.

VO = Volatile organics.

NA = Not available.

 a Air influent to stripper is not included because no concentration data were available.

^bGas-phase carbon adsorber effluent to atmosphere.

^cConcentrations given as both volatile and semivolatile fractions. Only volatile fraction data used.

dComponent concentration below detection limit.

^eConcentration reported for all isomers of dichlorobenzene, not just 1,2-dichlorobenzene.

		Water							
	Influ to str	ent ipper	Efflu from st	ent ripper	Air				
Constituent	Mass flow rate, x 10 ⁶ kg/h	Conc., µg/L	Mass flow rate, x 10 ⁶ kg/h	Conc., µg/L	organic removal efficiency, wt %				
1,2,3-Trichloropropane ^a (o,m)-Xylenes ^a p-Xylene ^C Toluene Aniline Phenol 2-Methylphenol 4-Methylphenol 1,4-Dichlorobenzene bis-(s-Chloroisopropyl) ether 2,4-Dimethylphenol 1,2,4-Trichlorobenzene Ethylbenzene Chlorobenzene Ethane, 1,1-oxybis	240,000 90,000 34,000 23,000 1,800 1,600 1,300 <41 98 710 110 160 710 820 780	29,000 11,000 4,100 2,800 226 198 160 <10b 12 87 13 19 87 100 95	220,000 39,000 18,000 12,000 1,200 780 900 5,700 39 340 41 110 340 90 250	27,000 4,700 2,200 1,500 141 95 110 7.1 4.8 42 <10 ^b 13 42 11 31	6.9 57 46 46 38 52 29 NA 40 51 >62 34 52 89 67				
[2-ethoxy- Other VO Total VO	8,000 1,800 400,000	980 220 49,100	7,700 980 300,000	940 120 37,000	4.1 45 25				

TABLE F-73. SOURCE TESTING RESULTS FOR STANDARD OPERATING CONDITIONS AT TSDF SITE 23, AIR STRIPPER

TSDF = Treatment, storage, and disposal facility.

NA = Not available.

VO = Volatile organics.

^CConcentrations given as both volatile and semivolatile fractions. Volatile fraction data used only.

^bConstituent concentration below detection limit.

TFE operated by an equipment manufacturer was tested in September 1986 as part of an EPA/HWERL program. The TFE was tested using two different wastes at different temperatures, flow rates; and pressures. The wastes tested at Site 28, emulsion tank sludge and oily tank bottoms, were selected based on their oil, water, solids, and organic content, which were similar to those for RCRA-listed refinery wastes, such as API separator sludge, that are currently land-treated. Temperature was varied between 150 and 340 °C. feed rate was varied between 0.010 and 0.073 kg/s•m² surface area, and the unit was operated both at atmospheric pressure and vacuum. Objectives of the tests included evaluating the process effectiveness and cost for organic removal from refinery waste sludges, estimating organic emissions and any other residuals from the process, and determining process limitations for treating hazardous wastes. Samples of feed, bottoms, overhead condensate, and condenser vent emissions were taken. Liquid samples were analyzed for volatiles by GC-FID headspace and purgeand-trap GC/MS. Liquid samples were analyzed for semivolatiles by acid/base/neutral solvent extraction--GC/MS. Condenser vent samples were analyzed by GC/MS.

A total of 22 tests were performed. Vent gas samples were speciated and quantitatively identified for one test, but the vent gas flow rate was too low (<10 cm³/min) to measure so that an estimate of process air emissions cannot be made on a compound-specific basis.

Mass balance data for test numbers 7 and 10 are presented in Tables F-74 and F-75. Operating conditions for test number 10 represent conditions that resulted in the highest organic removal efficiencies. Test number 10 was conducted at atmospheric pressure, high operating temperature (approximately 312 °C), and a feed rate of 0.018 kg/s $(0.064 \text{ kg/s} \cdot \text{m}^2)$ of surface area). As illustrated by test number 7, removal efficiencies were only slightly lower when the TFE was operated at low temperatures (150 °C), and substantially less water was evaporated along with the organics, reducing the need for additional treatment to separate the aqueous and organic phases. Operation under a vacuum at high temperatures resulted in problems of feed carryover into the condensate. The condensate from the vacuum runs was a milky-white emulsion requiring additional treatment to separate the oils.

F-160

						Conde	nsate			
	For	Jub	Bot	toms	Aqueou	s phase	0		Organic	
	F ee	-u-	Flow,		Flow,		<u><u> v</u>r<u>Bau</u>ic</u>	pnase	removal	
	Flow,	Conc.,	kg/h	Conc.,	kg/h	Conc.,	Flow,	Conc.,	efficiency, ^c	Air
Constituent	kg/h	mg/kg	(×1Ø ³)	mg/kg	(×1Ø ³)	mg/kg	kg/h	mg/kg	%	emissions
Benzene	0.016	230	<0.039	(Ø.62 ⁰		f	0.0073	6,000	99.739	NA
Toluene	Ø.19	2,800	Ø.38	6.1			0.15	120,000	99.78	NA
Ethylbenzene	0.012	180	Ø.13	2.1			0.0095	7,800	98.83	NA
Styrene	0.011	16Ø	0.16	2.5			0.0061	5,000	98.44	NA
m−Xylene	0.019	280	0.24	3.8			0.012	9,700	98.64	NA
o,p-Xylene	0.019	280	Ø.28	4.4			0.018	14,600	98.43	NA
Phenol	NA	NA	NA	NA			NA	NA	NA	NA
Benzyl alcohol	NA	NA	NA	NA			NÅ	NA	NA	NA
2-Methylphenol	NA	NA	NA	NA			NA	NA	NA	NA
4-Methylphenol	NA	NA	NA	NA			NA	NA	NA	NA
2,4-Dimethylphenol	NA	NA	NA	NA			NA	NA	NA	NA
bis(2-Ethylhexyl)phthalate	NA	NA	NA	NA			NA	NA	NA	NA
Naphthalene	0.052	765	32.76	520			0,0061	5.000	32.03	NA
2-Methylnaphthalene	0.054	790	41.58	66Ø			0.0037	3.000	16,46	NA
Acenaphthylene	0.0014	21	<2.52	(40 0			<0.00031	<25Ø€		
Acenaphthene	0.0032	47	<2.52	(400			<0.00031	(25Ø®		
Dibenzofuran	0,0025	37	0.063	26			(0.00031	(25Ø ^e	29.73	NA
Fluorene	0.0058	86	3.40	54			0.000077	63	36.84	NA
Phenanthrene	0.015	225	12.60	200			0.000049	40	11.11	NA
Anthracene	0.0014	20	1.13	18			<0.00031	<25Ø ^e	10.00	NA
Pyrene	0.0028	41	1.51	24			(0.00031	<25Øe	40.74	NA
Benzo (a) anthracene	0.0013	19	1.39	22			(0.00031	<25Ø ^e	-15.79	NA
Chrysene	0.0022	32	1.95	31			(0.00031	(25Ø ^e	3.13	NA
Di-n-octylphthalate	0.0012	18	NA	NA			NA	NA	NA	NA
Benzo fluoranthened	0,00089	13	0.82	13			(0.00031	(25Ø ^e	0.00	NA
Benzo(a)pyrene	0,00096	14	Ø,76	12			(0.00031	<25Ø®	14.29	NA

TABLE F-74. PERFORMANCE OF THIN-FILM EVAPORATOR RUN #7 AT SITE 28 FOR TREATMENTS OF PETROLEUM REFINERY EMULSION TANK SLUDGE^a

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NA = Not available.

^aUsed 0.069 kg/s·m² of surface area of refinery waste similar to API separator sludge processed at approximately 150 °C.

 $^{
m b}$ Feed data are averages of two analyses on the semivolatile and volatile fractions.

^cBased on mass flow rates of feed and bottoms.

^dIncludes two coeluting isomers.

•Below detection limit.

^fCondensate sample not analyzed for this run.

9Uses reported detection limit of 0.62 mg/kg for benzene.

-

						Conde	ensate			
			Bot	toms	Aqueou	s phase			Occanic	
	Fee	9qp	Flow,		Flow,		Organic phase		removal	
	Flow,	Conc.,	kg/h	Conc.,	kg/h	Conc.,	Flow,	Conc.,	efficiency, ^c	Air
Constituent	kg/h	mg/kg	(×1Ø ³)	mg/kg	(×10 ³)	mg/kg	kg/h	mg/kg		emissions
Benzene	0.015	230	0.0047	0.56	0.071	1.4	0.011	1,900	99.76	NA
Toluene	0.19	2,800	0.023	2.7	0.234	4.6	0.20	34,000	99.9Ø	NA
Ethylbenzene	0.012	180	0.0033	0.39	0.0081	0.16	0.14	24,000	99.78	NA
Styrene	0.010	160	0.010	1.2	0.0076	Ø.15	0,0076	1,300	99.25	NA
m-Xylene	0.018	280	0.0060	0.71	0.011	0.21	0.016	2,800	99.75	NA
o,p-Xylene	0.019	280	0.0061	Ø.72	0.010	0.2	0.029	4,900	99.74	NA
Phenol	NA	NA	NA	NA	0.011	0.21	NA	ŃA	NA	NA
Benzyl alcohol	NA	NA	NA	NA	0.0050	0.098	NA	NA	NA	NA
2-Methylphenol	NA	NA	NA	NA	0,028	0.55	NA	NA	NA	NA
4-Methylphenol	NA	NA	NA	NA	0.021	0.41	NA	NA	NA	NA
2.4-Dimethylphenol	NA	NA	NA	NA	0.0086	0.17	NA	NA	NA	NA
bis(2-Ethylhexyl)phthalate	NA	NA	NA	NA	0.0011	0.022	NA	NA	NA	NA
Naphthalene	0.050	765	0.20	24	0.071	1.4	0.032	5,400	96.86	NA
2-Methylnaphthalene	0,051	790	0.84	99	0.038	0.74	0.035	6,000	87.47	NA
Acenaphthylene	0.0014	21	0.12	14	<0.010	<0.2 ⁰	0.0011	190	33.33	NA
Acenaphthene	0.0031	47	<0.28	<33 ^e	(0.010	(0.20	0.0018	300	>90	NA
Dibenzofuran	0.0024	37	0.25	30	<0.010	(0.20	0.0015	260	89.48	NA
Fluorene	0.0056	86	0.75	89	0.0051	0.1	0.0034	580	86.50	NA
Phenanthrene	0.015	225	3.6	430	0.0049	0.096	0.0044	750	75.21	NA
Anthracene	0.0013	20	3.6	430	<0.010	<0.2 ^e	0.00032	Б4	NA	NA
Ругеле	0.0027	41	0.67	80	(0.010	<Ø.2 ⁰	0.00035	60	74.38	NA
Benzo(a)anthracene	0.0012	19	0.32	38	(0.010	(0.20	(0.0029	<500 ^e	74.06	NA
Chrysene	0.0021	32	0.73	86	(0,010	<0.2 ^e	(0.0029	(500°	65.14	NA
Di-n-octviphthalate	0.0012	18	NĂ	NA	NA	NĂ	NA	NA	NA	NA
Benzo fluoranthened	0.00085	13	0.41	49	(0.010	(0.20	(0.0029	<500 ^e	51.11	NA
Benzo (a) pyrene	0.00091	14	0.26	31	(0.010	(0.20	(0.0029	<500°	71.28	NA

TABLE F-75. PERFORMANCE OF THIN-FILM EVAPORATOR RUN ∦10 AT SITE 28 FOR TREATMENTS OF PETROLEUM REFINERY EMULSION TANK SLUDGE^a

NA = Not available.

^aUsed 0.064 kg/s·m² of surface area of refinery waste similar to API separator sludge processed at approximately 312 °C.

^bFeed data are averages of two analyses on the semivolatile and volatile fractions.

^cBased on mass flow rates of feed and bottoms.

dIncludes two coeluting isomers.

Below detection limit.

Several conclusions were drawn from the pilot-scale test of a TFE. TFEs are able to process nonhazardous feed streams such as oily refinery sludges and were found to have high removal efficiencies of volatile organic compounds from the waste sludges tested. Removal efficiency for volatile organics was greatest when the TFE was operated at the highest temperature (320°C). Removal efficiencies from semivolatiles ranged from 10 to 75 percent depending on operating conditions. When operated at high temperatures and under vacuum, some carryover of feed into the condensate was observed, with the condensate being a milky-white emulsion requiring additional treatment. Foaming of the feed reduces the heat transfer to the material being processed. Flow rates and total volatile organic emissions from the condenser were highly dependent on the waste being processed; lower condenser temperatures were capable of substantially reducing emissions. The capital and operating costs of using TFE to process petroleum waste sludges under various operational modes are significantly less than the cost of land treatment. The effectiveness of TFE as an emission control strategy was evaluated by subjecting TFE-treated waste to a land treatment simulator program and is described in Section F.1.4.1.

F.2.3.3.2 <u>Site 29</u>.95 Contaminated organic solvents from a variety of waste sources are processed at the Site 29 facility, a waste solvent recycler. Three separate processes are used to treat the different wastes. A batch thin-film evaporator is used to treat waste paint and lacquer thinners, and an azeotropic steam injection distillation unit is used to purify chlorinated solvents. These two units process most of the waste that is treated at the facility. The other treatment process available is flash distillation, which usually is used for single- or two-component mixtures of alcohols, glycols, or aromatic or aliphatic solvents. The thin-film evaporator and the steam injection distillation unit were tested from August 18 through 21, 1986, but the flash distillation was not tested. steam injection distillation unit test results are presented in Section F.2.3.4.1.

The paint and lacquer wastes are pumped from a feed tank into the batch Kontro thin-film evaporator unit. The evaporator operates under a

vacuum, and heat is provided through a steam jacket to generate the overhead vapor. The vapor is condensed and collected in a product receiver tank before being discharged to a larger product storage tank at atmospheric pressure. The bottoms stream is collected and utilized as a supplemental fuel for offsite asphalt kilns. The recovered solvents are recycled.

The evaporator has a heat transfer surface area of 1.9 m^2 . During testing, the feed rate was 0.24 L/s. The system was operated at a pressure of 47 kPa. Steam was fed to the system at 1,140 kPa and 185 °C, but the rate was not specified. A heating capacity of 2×10^6 Btu/h was given, which corresponds to approximately 760 kg/h of steam, if the system is run at maximum capacity.

The objective of the field test of the thin-film evaporation process at Site 29 was to determine how efficiently it removes volatiles from hazardous waste streams. Liquid samples were collected from the evaporator feed stream, evaporator bottoms, and condensate. Samples of the liquid influent and effluent streams were collected in 40-mL VOA bottles and 1-L amber glass bottles, depending on the analysis to be performed. These grab samples were apparently combined to yield composite samples, but it was not specified how often the samples were collected and how they were composited. Gas samples were taken at selected locations by pumping air through charcoal tubes. This analysis yielded component concentrations in the air, but vent gas velocities were not measured and emission rates for these compounds could not be calculated.

The test run for the thin-film evaporator was performed over a period of 6.75 hours. Process data collected for the thin-film evaporator included: (1) feed, bottoms, and condensate tank volumes at the beginning and end of the process; (2) overhead product, bottoms, and liquid sample temperatures; (3) system pressure; and (4) steam temperature and pressure.

The analysis technique used for the gas samples collected in the charcoal tubes was not given. VO concentrations in the liquid samples were determined by GC-FID. VO identification was confirmed by direct-injection GC-MS for each sample. Water concentration was determined using ASTM Method D1744.⁹⁶ Material balances were used to characterize the operation and resultant conditions of the thin-film evaporator. Table F-76 presents the source testing results for the Site 29 thin-film evaporator. The organic removal efficiency was calculated based on the constituent flow rates in the feed and the bottom streams to show the amounts actually removed from the feed.

F.2.3.3.3 <u>Site 30</u>.⁹⁷ On August 31, 1984, a field evaluation of the Site 30 thin-film evaporator was performed. Site 30 uses thin-film evaporation for the reclamation and recycle of organic solvents. The primary activity at Site 30 is the reclamation of organic solvents and contaminated products for recycle or sale. Specialty solvent blends that are optimized for specific client uses also are produced. The solvent recovery processes include two V0 recovery systems: a Luwa thin-film evaporator and one SRS, Riston Batch Distillation.

Support facilities include a drum storage and management area, a cooling water system, an oil-fired boiler for steam generation, an air compressor, a bench-scale Rodney-Hunt thin-film evaporator, storage tanks, and associated pumps and piping.

The wastes processed by Site 30 are from the chemical, plastics, paint, adhesive film, electronics, and photographic industries. The types of chemicals recovered include chlorinated solvents, freons, ketones, and aromatic hydrocarbons. Approximately 1,200 Mg/yr VO are recovered. There is currently no vacuum system and consequently no capability for operating the Luwa evaporator under reduced pressure. This precludes processing of high-boiling compounds such as naphtha and xylene.

The contaminated organic solvents to be treated are charged to the feed recirculation tank of the batch process thin-film evaporator. Steam is used to heat the liquid pumped into the evaporator, generating the overhead product that is condensed and pumped into a product tank. The evaporator bottoms are pumped back to the feed tank and recirculated through the evaporator until a predetermined VO removal is attained. The final bottoms residues are utilized as fuel, if possible, or are solidified with diatomaceous earth and landfilled. Overhead products are recycled or sold.

	<u>Influent</u>	to TFE	Bottoms from TFE		Overhead condensate		TFE organic removal	Process air	
Constituent	Flow, kg/h	Conc., ppmw	Flow, kg/h	Conc., ppmw	Flow, kg/h	Conc., ppmw	efficiency, wt %	emissions, ^a Mg/yr	
Xylenes	49	66,000	76	210,000	33	84,300	NA	NA	
Acetone	140	190,000	1.9	5,200	71	183,000	99	NA	
Ethyl acetate	8.1	11,000	<4.4	<12,000 ^b	4.6	11,700	>45	NA	
Ethyl benzene	16	22,000	17	48,000	11	28,300	NA	NA	
Methyl isobutyl ketone	1Ø	14,000	2.0	5,600	6.2	16,000	8Ø	NA	
n-Butyl alcohol	8.1	11,000	<2.Ø	<5,600 ^b	5.1	13,000	>75	NA	
Toluene	16Ø	220,000	29	81,000	95	243,000	82	NA	
Methyl ethyl ketone	130	180,000	21	57,000	87	223,000	84	NA	
Isopropanol	56	76,000	<2.0	<5,600 ^b	33	83,700	>96	NA	
Total VO ^c	58Ø	790,000	15Ø	420,000	350	890,000	74	NA	
Other9	14Ø ^d	NA	18Ø ^e	NA	25 ^h	NA	NA	NA	

TABLE F-76. SOURCE TESTING RESULTS FOR TSDF SITE 29, THIN-FILM EVAPORATOR

TSDF = Treatment, storage, and disposal facility.

TFE = Thin-film evaporator.

NA = Not available.

VO = Volatile organics.

^aEmission rates could not be calculated because vent gas velocities were not measured.

^bConstituent concentrations below detection limit.

CTotal of all identified volatile organics.

^dThis includes some mineral spirits not analyzed for and other unknowns.

^eBalance of total flow after accounting for organics and water.

The batch process evaporator has a heat transfer surface area of 1.0 m^2 and operates at atmospheric pressure. The feed circulation tank has a volume of 1.7 m^3 from which the contents are pumped into the evaporator at a rate of 1,390 kg/h. Steam entered the system at 310 kPa and 135 °C for this test, but it can be used over a range of 310 to 650 kPa, depending on the solvent processed.

The objective of the field test of the thin-film evaporation process at Site 30 was to determine how efficiently it removes volatiles from hazardous waste streams. Liquid samples were collected from the evaporator feed stream, evaporator bottoms, and condensate. Gas samples were collected from the condenser vent. Sampling of the treated waste was done at the end of the process, but the other samples were taken during the first third of the waste treatment cycle. Process data included feed, steam, overhead product, bottoms, and vent gas flow rates, temperatures, and pressures.

Material and energy balances and stream flow and concentration data were used to characterize all process streams around the Site 30 thin-film evaporator. Table F-77 presents the source testing results. The organic removal efficiency was calculated on the basis of influent and effluent flow rates of a constituent in the thin-film evaporator. The composition for the overhead condensate is presented but is not used to calculate removal efficiencies. This is done because the sampling time of the overhead product was unspecified. The feed and bottoms were sampled at the beginning and end of the run, respectively. Because of the recirculation of the feed volume, the overhead concentration would change during the process. Computing the organic removal efficiency this way also removes the effect of any receiver tank contamination or background interference in the liquid by looking at the actual amount of organic removed from the same bulk volume of material.

F.2.3.3.4 <u>Site 22</u>.⁹⁸ The primary activity at Site 22 is the recovery of organic wastes and contaminated chemicals. The company also engages, to a lesser extent, in waste management for some firms.

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Constituent	Influent waste conc., ppmw	Treated waste conc., ppmw	Overhead condensate ^a conc., ppmw	Thin-film evaporator organic removal efficiency,b wt %
Acetone	690,000	550,000	770,000	76
Xylene	60,000	140,000	21,000	30
1,1,1-Trichloroethane	23,000	14,000	34,000	82
Toluene	5,100	3,000	9,300	82
Tetrachloroethylene	11,000	17,000	9,600	54
Trichloroethylene	3,500	850	5,200	93
Freon TF	1,900	1,800	1,900	72
Ethyl benzene	<1,020°	500	3,100	<85
Total VO ^d	800,000	730,000	860,000	73

TABLE F-77. SOURCE TESTING RESULTS FOR TSDF SITE 30, THIN-FILM EVAPORATOR

TSDF = Treatment, storage, and disposal facility. VO = Volatile organics.

vo - votacile organics.

 $^{\mbox{a}}\mbox{Sampled}$ at the same time as the waste.

^bVO removal is estimated based on 70 percent recovery (i.e., 70 percent reduction in waste volume), e.g.,

 $\begin{array}{r} \mbox{Treated waste} x \ (1-0.7) \\ \mbox{Overhead removal wt } \mbox{\ensuremath{\$}} = \ (1 \ - \ \frac{\mbox{conc.}}{\mbox{Influent waste conc. } x \ 1} \) \ x \ 100\% \ . \end{array}$

 $^{\rm C}{\rm Constituent}$ concentration was below detection limit. $^{\rm d}{\rm Total}$ of all identified VO.

The recovery and purification processes involve three VO recovery systems:

- One Luwa thin-film evaporator
- One batch fractionation distillation column
- One continuous feed fractionation distillation column.

Support facilities include a concrete drum storage and management area, a cooling water system, an activated sludge wastewater treatment system, an oil-fired boiler system for steam generation, and a main building providing housing for offices, laboratories, and locker rooms.

On July 26, 1984, a field evaluation of the thin-film evaporator was conducted. The Luwa thin-film evaporator processes organic wastes from the furniture, chemical, dry cleaning, and paint industries. Wastes processed include furniture finishing wastes and other organic wastes that could contain sludges. The sludge would include paint films, particulates, and insoluble organic materials. Approximately 7,500 Mg/yr of VO are recovered overhead.

Batches of organic waste, contaminated solvents, and organic byproducts are pumped into the Luwa thin-film evaporator, where the more volatile organics are evaporated under vacuum and condensed overhead. The overhead product may be further refined through fractional distillation or reused elsewhere. The evaporation is operated so the remaining bottom residue retains sufficient heat value to be used as fuel in kilns or incinerators.

The evaporator heat transfer surface area is 4.0 m². Typically, the feed rate is 0.38 L/s, with 70 to 95 percent of the material taken as overhead product. The system can be operated at a pressure of about 6.66 kPa or 46.6 kPa, depending on the vacuum pump system used. Steam is fed to the system at.a temperature of 55.6 °C above the boiling point of the feed and at a rate of about 190 kg/h, although the pressure is unspecified.

The objective of the field test of the thin-film evaporation process at Site 22 was to determine how efficiently it removes volatiles from hazardous waste streams. Liquid samples were collected from the influent to the evaporator, evaporator bottoms, and condensate. Air emission samples were collected from the vacuum pump vent. Process data also were recorded during sampling. One grab sample was taken for each liquid sampling point, with both the liquid and the equilibrium vapor being analyzed. Vent air samples were collected in carbon adsorption tubes and analyzed for VO.

Measured concentration data and an assumed 95-percent organic removal were used along with the feed flow and material and energy balances to characterize all process streams around the thin-film evaporator. Table F-78 presents the source testing results for the Site 22 thin-film evaporator. Much of the high-boiling hydrocarbon mixture was removed overhead, leaving only sufficient amounts of hydrocarbons to give an acceptable viscosity in the bottoms.

F.2.3.4 Batch Distillation.

F.2.3.4.1 <u>Site 29</u>.⁹⁹ The Site 29 facility is a waste solvent recycler as is described in Section F.2.3.3.2. Tests were performed on the steam injection distillation unit from August 18 through 21, 1986.

Chlorinated solvents are charged to a kettle in the steam injection distillation unit in a batch operation. Steam is injected into the tank to give turbulent mixing and to evaporate the solvents. The overhead stream is condensed and collected in a receiver tank, from which it is sent to a decanter. When enough water has accumulated on top of the organic product, the water is drawn off and discharged to an aeration pond and then to the sewer. The recovered solvent is pumped to a calcium chloride drying column to remove any remaining water before being recycled. The water from the drying column is diluted and discharged to the sewer. The residue in the kettle is deep-well injected.

The horizontal steam injection kettle has a capacity of 3.8 m^3 . Steam is supplied at about 184 kPa and 117 °C. The steam feed rate was estimated to be about 300 kg/h, but this was not measured.

The objective of the field test of the steam injection distillation unit system at Site 29 was to determine how efficiently it removes volatiles from hazardous waste streams. Two batch tests were performed with the steam injection distillation unit system. The first batch contained

	Influe	nt to TFE	Effluent	; from TFE	Overl condei	nead nsate	TFE organic removal efficiency,b wt %	
Constituent	Flow, kg/h	Conc., ppmw	Flow, kg/h	Conc.,ª ppmw	Flow, kg/h	Conc., ppmw		
Methylene chloride	6.0	26,000	Ø.ØØ5	46Ø	2.6	12,000	99.1	
Chloroform	5.1	22,000	ø	ø	Ø.16	75Ø	>99.99	
1,1,1-Trichloroethane	2.1	9,100	0.01	91Ø	Ø.146	67Ø	>99.5	
Toluene	2.5	11,000	Ø.36	33,000	3.05	14,000	<85.Ø	
Freon TF	Ø.2	78Ø	0.003	300	6.2	28,500	80	
Hydrocarbon mixture	2Ø3	930,000	11	NA	2Ø5	940,000	NA	
Total VO ^C	23Ø	NA	11 ^d	NA	2Ø8	NA	NA	

TABLE F-78. SOURCE TESTING RESULTS FOR TSDF SITE 22, THIN-FILM EVAPORATOR

TSDF = Treatment, storage, and disposal facility.

TFE = Thin-film evaporator.

VO = Volatile organics. NA = Not available.

^aEstimated based on headspace analysis.

^bBased on reduction in headspace concentration.

^cSum of quantified VO.

 $^{\rm d}{\rm Based}$ on 95 percent of the feed taken overhead.

methylene chloride as the major constituent, and the second one contained 1.1.1-trichloroethane as the major component.

The two batches in the steam injection distillation unit were sampled and monitored similarly. Liquid samples were collected in 40-mL VOA bottles and 1-L amber glass bottles. These samples were taken of the waste feed, the final injection kettle residue, the overhead organic condensate, and the overhead aqueous condensate for both runs. Although the time at which the overhead condensate samples were taken was unspecified, it was assumed that they were taken at the end of the process when the sample would be a composite of the condensate collected from the entire batch. The waste feed for run 1 was composed of 22 drums of waste, of which 14 were initially in the kettle. The remaining eight drums were added shortly after batch startup. A sample of the waste feed was collected after the addition and mixing of all the waste feed. The waste feed for run 2 consisted of nine drums of material, and samples were taken of each drum and combined to yield a representative sample of the feed. The techniques used for determining VO and water concentration were the same as those used for the thin-film evaporator samples. Gas samples were collected at selected locations by pumping air through charcoal tubes. This analysis yielded constituent concentrations in the air, but vent gas velocities were not measured and emission rates for these compounds_could not be calculated.

The first batch of waste was processed for 5 h on 1 day and for an additional 3.5 h on the next day. The second batch was completely processed in 1.9 h. Process data collected included: (1) injection kettle and overhead product tank volumes at the beginning and end of the process, (2) overhead, distillate, and tank temperature at various times during the process, and (3) steam temperature and pressure.

Table F-79 presents the source testing results for both batches. The organic removal efficiency is based on the constituent mass in the steam injection kettle at initial and final conditions to show the amount of a constituent actually removed from the waste during the process.

F.2.3.4.2 <u>Site 31</u>.¹⁰⁰ The primary activity at Site 31 is the reclamation of contaminated solvents and other chemicals through

						Overhead	condens	ate	Steam		
	Initial kettle charge		Final kettle residue		Aqueous Mass.		Organic		organic removal	Process air	
Constituent	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw	× 10 ³ kg	Conc., ppmw	Mass, kg	Conc., ppmw	efficiency, wt %	emissions, ^a Mg/yr	
Batch 1											
Tetrachioroethylene	390	82,000	43	11,000	<5.8	<18Ø ^b	13	3,800	89	NA	
Methylene chloride	2,200	450,000	18Ø	45,000	24Ø	7,500	2,500	760,000	92	NA	
Carbon tetrachloride	3.3	68Ø	<Ø.64	<16Ø ^b	<5.8	<18Ø ^b	6.3	1,900	>8Ø	NA	
Chlorobenzenø	1.6	33Ø	3.4	86Ø	<5.8	<18Ø ^b	<0.60	<18Ø ^b	, NA	NA	
Trichloro-trifluoroethane	32	6,600	<4.Ø	<1,000 ^b	35	1,100	<0.60	<18Ø ^b	>87	NA	
Dichlorobenzene	Ø.91	190	<1.3	<32Ø ^b	<5.8	<18Ø ^b	Ø.56	170	NA	NA	
Xylenes	4.8	1,000	3.Ø	78Ø	<5.8	<18Ø ^b	5.3	1,600	38	NA	
Ethyl acetate	46	9,600	8.2	2,100	<5.8	<18Ø ^b	13	3,800	82	NA	
Isopropanol	67Ø	140,000	43Ø	110,000	2,200	68,000	31Ø	94,000	36	NA	
Methyl isobutyl ketone	<1.1	<22øb	11Ø	29,000	<5.8	<18Ø ^b	1.2	37Ø	NA	NA	
Total VOC	3,300	690,000	78Ø	200,000	2,500	77,000	2,900	870,000	76	NA	

TABLE F-79. SOURCE TESTING RESULTS FOR TSDF SITE 29, STEAM DISTILLATION UNIT

See footnotes on next page.

(continued)

						Overhead	condensa	te	Steam — distillation	
	Initial		Fi	Final		leous			organic	
Constituent	Mass, kg	e charge Conc., ppmw	Mass, kg	Conc., ppmw	Mass, x 10 ³ kg	Conc., ppmw	Mass, kg	Conc., ppmw	removal efficiency, wt %	Process air emissions, ^a Mg/yr
Batch 2				-						
Tetrachloroethylene	2.3	1,200	<3.Ø	<3,800 ^b	<9.2	<22ø ^b	Ø.Ø9	<16Ø ^b	' NA	NA
Trichloroethylene	3.8	2,000	<3.Ø	<3,800 ^b	<9.2	<22ø ^b	0.09	<16Ø ^b	>21	NA
Methylene chloride	6.1	3,200	<3.Ø	<3,800 ^b	<9.2	<22ø ^b	Ø.Ø9	<16Ø ^b	>51	NA
1,1,1-Trichloroethane	1,060	560,000	91	112,000	<9.2	<22ø ^b	92Ø	840,000	91	NA
Chlorobenzene	1.6	86Ø	<3.Ø	<3,800 ^b	<18	<22Ø ^b	1.8	<3,200 ^b	NA	NA
Trichloro-trifluoroethane	6.1	3,200	<3.Ø	<3,800 ^b	<84	<2,000 ^b	8.7	7,900	>51	NA
Xylenes	1,9	1,000	<3.Ø	<3,800 ^b	<9.2	<22øb	0.09	<16Ø ^b	NA	NA
Methyl isobutyl ketone	2.3	1,200	<3.Ø	<3,800 ^b	<9.2	<22Ø ^b	Ø.Ø9	<16Ø ^b	NA	NA
Isopropanol	3.4	1,800	<3.Ø	<3,800 ^b	39Ø	9,400	7.0	6,400	>12	NA
Total VO ^c	1,090	574,000	91	112,000	39Ø	9,400	94Ø	850,000	91	NA

TABLE F-79 (continued)

TSDF = Treatment, storage, and disposal facilities. NA = Not available. VO = Volatile organics.

^aEmission rates could not be calculated because vent gas velocities were not measured.

^bConstituent concentration below detection limit.

CTotal of all identified VO.

evaporation and distillation. About 10 percent of the incoming chemicals are contaminated products, with the remainder being classified as hazardous waste. Approximately 85 percent of the reclaimed chemicals are recycled back to the generator with the remainder being marketed to suitable end users.

Processing equipment includes two Votator agitated thin-film evaporators, two distillation reboilers, eight fractionation columns, and one caustic drying tower. Support facilities include 97 storage tanks (3,790-m³ capacity); two warehouses containing dyked concrete pads for drum storage; an analytical laboratory; gas-fired steam generation; and an office building. A fleet of tractors and vacuum tankers is maintained for transporting solvents and chemicals to and from the plant.

On December 19 and 20, 1984, field tests were conducted on the distil lation systems. The wastes processed by Site 31 are from the chemical, paint, ink, recording tape, adhesive film, automotive, airlines, shipping, electronic, iron and steel, fiberglass, and pharmaceutical industries. The types of chemicals recovered included the following VO: alcohols, ketones, esters, glycols, ethers, chlorinated solvents, aromatic hydrocarbons, petroleum naphthas, freons, and specialty solvents. Distillation units one and two recover 560 Mg/yr and 1,400 Mg/yr VO, respectively. Contaminated organic chemicals and solvents are received in bulk and drum shipments and processed for reclamation and recycle.

All waste material is processed first either in the thin-film evaporator or in the distillation reboilers. Approximately 90 percent of the incoming shipments are processed through one of two Votator thin-film evaporators during which about 80 percent of the material is stripped off as overhead product. The limiting factor for the amount of liquid that can be recovered is that the bottoms product must be acceptable in heat value and viscosity for offsite consumption as fuel. The overhead product may or may not be further refined through fractionation distillation, depending on the intended end use. Thin-film evaporator bottoms are shipped offsite and utilized as fuel in cement kilns.

. There are eight fractionation distillation systems of varying capabil ity and capacity at the Site 31 facility. The fractionation distillation

systems each consist of a reboiler, a tray column and condenser, an accumulator, and associated pumps, valves, and piping. Instrumentation includes a reboiler and column head vapor temperature recorders (multipoint recorder) and rotameters in the reflux and product lines. The system selected for any particular separation is dependent on a number of factors such as throughput, relative vapor pressures, and required purity of the process streams.

A variety of organic and aqueous wastes can be processed through the distillation columns at Site 31. These trials, however, were restricted to wastewaters containing fairly low concentrations of VO. The reboiler of a distillation system is charged initially with a wastewater quantity, depending on the distillation system used. Steam is applied to the coil of the reboiler, causing the organics and water to boil out of the waste. The vapors pass through a distillation column where the VO are separated from the wastes and then are condensed and sent to a vented product storage tank. The distillation process continues until the VO content in the aqueous volume is less than 0.10 percent. The reboiler contents then are discharged to a hazardous treatment site or to the municipal WWT system, depending on the contaminants present. After sufficient accumulation of similar overhead products in storage, the recovered organics are sent directly to specific clients or are refined further before being sent to the clients. The need for further refining depends on the end-use of the product and cannot be characterized because of the wide variety of wastes processed.

The objective of the field tests of batch distillation systems at Site 31 was to determine how efficiently they remove volatiles from hazardous waste streams. Two separate, but similar, distillation systems were tested at the facility. Distillation unit one has a reboiler capacity of 42 m³, with a 1.07-m diameter, 30-tray distillation column. The trial used a reboiler charge of 30 m³. Steam was fed to the reboiler coil at 960 kPa at a rate of 820 kg/h. The temperature of the steam was not specified. Distillation unit two has a reboiler capacity of 13 m³, with a 0.81-m, 30-tray distillation column. The trial used a reboiler charge of 11 m³. The same quality steam was fed to the reboiler coil at a rate of 590 kg/h. Liquid samples were collected from the charge to the reboiler, final aqueous residue from the reboiler, and final overhead condensate. Gas samples were taken from the condenser, receiver, and product accumulator vents. Sampling was conducted for the batches in units one and two over periods of 15.0 and 11.5 h, respectively, with samples taken at the start and end of the process, and at least two times during the fractionation. Liquid grab samples were collected in 40-mL VOA bottles. Vent gas samples were collected in evacuated stainless-steel canisters. Process operating data were collected throughout the distillation process. Process data included initial batch charge, estimated steam flow rate, reboiler and column head temperature, reflux rate, and vent velocity and temperature.

Vent gas was analyzed by GC. The VO compounds in the liquid samples were identified and quantified by both direct injection GC and headspace GC. Material and energy balances were used to characterize the operation and resultant conditions of the fractional distillation units. The source testing results are presented in Tables F-80 and F-81 for Site 31 distillation units one and two, respectively. The organic removal efficiency was calculated on the basis of initial and final mass of a constituent in the reboiler. No composition data were available for the overhead condensate, so the values presented for final overhead condensate were calculated by assuming that all the initial organics in the reboiler, except what remained at the end of the process, were collected as overhead condensate. F.2.4 Other Process Modifications

F.2.4.1 <u>Subsurface Injection of Land-Treated Waste--Site 19</u>.¹⁰¹ Section F.1.4.2 describes the test program conducted during the period of October 9, 1984, through November 2, 1984, on the land treatment site at the Site 19 refinery. One of the objectives of the test program was 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. Sludge was surface-applied on Plot A and subsurface-injected into Plot C.

Subsurface injection as practiced at this refinery did not appear to have a large effect on the emissions. Immediately after sludge application and before first tilling, the cumulative 2-day measured emissions from the

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Constituent	Initial charge to reboiler		Final aqueous residue from reboiler		Final overhead condensate		Distillation organic removal	Process air
	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw	efficiency, wt %	emissions,a Mg/yr
Methyl ethyl ketone	900	30,000	<0.3	<10 ^b	900	640,000	>99.97	2.5
2,2-Dimethyl oxirane	19Ø	6,400	<0.3	<10 ^b	19Ø	140,000	>99.8	Ø.52
Methanol	110	3,500	<0.3	<1Ø ^b	110	78,000	>99.7	Ø.3Ø
Methylene chloride	93	3,100	<0.3	<10 ^b	93	66,000	>99.7	Ø.26
Isopropanol	57	1,900	<0.3	<1Ø ^b	57	41,000	>99.5	Ø.16
Carbon tetrachloride	51	1,700	<0.3	<1Ø ^b	51	36,000	>99.4	Ø.14
1,1,1-Trichloroethane	21	71Ø	15	53Ø	6	4,300	29	Ø.Ø17
Other VO	64	2,200	<0.9	<3Ø	63	45,000	>98	Ø.17
Total VO ^C	1,400	49,000	15	53Ø	1,400	1,000,000	>99	4.1

TABLE F-80. SOURCE TESTING RESULTS FOR TSDF SITE 31, FRACTIONAL DISTILLATION UNIT ONE

TSDF = Treatment, storage, and disposal facility. VO = Volatile organics.

^aCondenser and product accumulator vent emissions. Condensate receiver vent emissions were negligible. ^bConstituent concentration below detection limit.

^cSum of VO identified by gas chromatography.

Constituent	Initial charge to reboiler		Final aqueous residue from reboiler		Final overhead condensate		Distillation organic removal	Process air
	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw	Mass, kg	Conc., ppmw	efficiency, wt %	emissions, ^a x 10 ³ Mg/yr
Acetone	2,400	212,000	6.0	69Ø	2,400	923,000	99.7	74
Trichloroethane	110	9,500	<0.09	<1Ø ^b	11Ø	42,000	>99.9	3.4
1,1,1-Trichloroethane	32	2,800	<0.09	<1Ø ^b	32	12,000	>99.7	Ø.98
Toluene	31	2,700	<0.09	<10 ^b	31	12,000	>99.7	Ø.95
Methyl ethyl ketone	26	2,300	<0.09	<10 ^b	26	10,000	>99.6	Ø.8Ø
Isopropanol	5.Ø	440	Ø.11	13	4.9	1,900	98	Ø.15
 Xylene and ethyl benzene	3.3	290	<0.09	<10 ^b	3.3	1,300	97	Ø.1Ø
Total VO ^c	2,600	230,000	6.1	700	2,600	1,000,000	99.8	8Ø

TABLE F-81. SOURCE TESTING RESULTS FOR TSDF SITE 31, FRACTIONAL DISTILLATION UNIT TWO

TSDF = Treatment, storage, and disposal facility. VO = Volatile organics.

^aCondenser, condensate receiver, and product accumulator vent emissions.

^bConstituent concentration below detection limit.

^cSum of VO identified by gas chromatography.

surface application plot were slightly greater than those from the subsurface application plot. After the first tilling episode (2 days after the initial application), the cumulative measured emissions seemed to be slightly greater for the subsurface application plot throughout the remainder of the test period. The total cumulative measured emissions were 14 percent greater from Plot C than from Plot A. Similarly, the estimated total emissions from Plot C (39.0 kg) were 17 percent greater than the total for Plot A (33.3 kg) for the 5-week test period. Therefore, based on the test data, there is no reduction in annual emissions resulting from subsurface injection at this location.

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APPENDIX G

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EMISSION MEASUREMENT AND CONTINUOUS MONITORING

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APPENDIX G

EMISSION MEASUREMENT AND CONTINUOUS MONITORING

G.1 EMISSION MEASUREMENT METHODS

G.1.1 Sampling

The purpose of the volatile organic (VO) test method is to gain an understanding of the VO emission potential of a particular waste. The accuracy of any analytical result becomes irrelevant if the sample is not representative of the total waste. A representative sample is defined as a small amount of waste that has the same VO per unit weight as the average of a much larger amount of waste. Included in the test method will be guidance in proper sampling and storage techniques to obtain a representative sample while minimizing VO loss during sample collection.

The primary emphasis to date has been in identifying proper procedures for sampling liquid wastes from a pipe. This is anticipated to represent the majority of the regulatory need. The following discussion provides insight into the current status of this aspect of the VO test method development.

There are two problems with sampling from a pipe:

a. The first is nonhomogeneity of the waste. A sample of a nonhomogeneous waste extracted from a wall tap would probably be biased. Turbulent flow creates a mixing action that will homogenize single-phase waste, but may not be enough to disperse and homogenize a multiphase waste.

b. The second problem is that VO can volatilize during sample collection. EMB has investigated VO loss from the handling, storage, and transfer of synthetic waste and has found significant losses for compounds with low solubility and high volatility. This investigation indicates a need to provide guidance in the test method to minimize this potential VO loss. Two types of sampling systems were considered to minimize these potential problems. These are discussed below.

A closed loop sampling system was considered because of its ability to sample representatively. The entire waste stream is diverted to a bypass loop. After purging the bypass loop with the waste, the waste is directed back through the waste line and the bypass loop is removed by a series of valves with the sample sealed inside. The sample container is essentially a length of pipe capped at both ends. Because an entire cross section of the waste stream is collected, the problem of nonhomogeneity of the waste stream is eliminated. The closed loop sampler does not leave a messy sampling site or expose the waste sample to the air; thus, VO loss is minimized. The sample loop can be shipped in ice to a lab for VO analysis. The closed loop sampling system works for the on-site tester but creates a problem for the lab. The lab must mix and aliquot a representative subsample while restricting VO loss. The actual sample container would also have to be designed to withstand potential extremes in pressure and temperature and to minimize back pressure during sample collection.

The second system considered was installation of a static mixer with the sample collected from a wall tap down stream of the mixer. This arrangement offers the tester more flexibility in the type of sample container used. A literature search has shown that properly designed static mixers are capable of dispersing and mixing an oily phase or a solid slurry into an aqueous phase. The static mixer can be installed in the sample line or in a bypass line. The cost of the mixers range from \$500 to \$5000, depending on materials and size. Once the phases are fully dispersed and homogenized, a tap sample is representative of the waste. Another advantage to this approach over using the closed loop sampler is that the sample containers can be less sophisticated, inexpensive, and more reliable. However, there is now exposure to the atmosphere during collection, so that precautions are needed to minimize V0 losses.

The sampling protocol will recommend a properly designed static mixer with the sample extracted from a wall tap after the mixer as the preferred method for sampling for VO. Guidance on what constitutes a properly designed static mixer and the acceptable location of the wall tap will be provided in the test method. To minimize VO loss during sample collection, the method will require the sample to be cooled to $\langle 4$ °C (40 °F) with a stainless steel cooling coil in an ice bath. After exiting the cooling coil, the waste will flow through a Teflon- tube to the bottom of a chilled sampling container. If the VO test method is a headspace analysis, the sample collection container will also be the container used in the analysis, and there would be no transfer of sample. If the VO test method requires the sample to be transferred to another container, then the volume of the sampling container will be defined as the volume needed for the analysis, and homogenizing and subsampling the sample in the lab will not be necessary. This also means that the sample can be stored with no headspace.

G.1.2 Analytical Approach

The analytical approach chosen to measure volatile emissions from waste was to develop a two-part method. First, the VO would be separated from the waste, then the VO would be measured by a suitable analytical technique.

The separation step was considered to be advantageous for two reasons:

a. By choosing a separation process based on the waste components vapor pressure, the separation step can be used to test what constitutes the waste's volatile fraction. By investigating different volatile separation techniques and varying the physical parameters of the chosen technique, the separation's removal efficiency might be matched or correlated with the emission potential from a variety of hazardous waste treatment, storage, and disposal facilities (TSDF).

b. Once the waste's volatile fraction has been separated, analyzing for organic constitutents in the volatile fraction is much easier. Organic analysis of whole waste samples is plagued with difficulties because of a

host of interfering components and unfavorable physical characteristics. The separated volatile fraction can be analyzed as either a vapor in a carrier gas, condensed as a pure compound, mixed with a carrier solvent, or adsorbed on a solid adsorbent. Any of these sample matrices would be free from a majority of the analytical difficulties encountered with whole waste.

Because the final decision as to whether to monitor for specific compounds, total organics, or a combination of both has not been made, several measurement techniques have been considered. If it is decided that only individual compounds are to be monitored, then the solid waste methods in SW-846 would provide validated methods for all Appendix IX compounds. These methods could be applied directly to the waste or adapted to analyze the volatile fraction separated during the test method.

Two different techniques have been investigated to provide a total organic analysis of the separated volatile fraction. The first technique collects the volatile fraction in or on a suitable media, such as a Tedlarbag or charcoal adsorbent for organic vapors and water for condensed organics. The collected fraction is then analyzed first by a commercially available total organic carbon analyzer, and then by a commercially available total halogen analyzer. The amount of carbon as methane and halogen as chlorine are added to approximate the total organic in the volatile fraction.

The second technique is to analyze the separated fraction immediately after the separation thereby eliminating the collection step. This technique should substantially improve the method's precision and provide immediate results. All the separation techniques considered involve a step in which the volatile components are in the vapor phase. A representative sample of this vapor fraction can be analyzed continuously or periodically throughout the separation with a combined total carbon and total halogen analyzer developed for this test method. The total organic analyzer, based on a flame ionization detector (FID) design, provides a signal throughout the separation process, whereas the total halogen analyzer traps the halogen ions in a solution that can be monitored electrochemically during

the separation or titrated at the end of the separation. Again, the amount of carbon and halogen are added to approximate the total organic in the volatile fraction.

G.1.2.1. <u>Evaluation Approach</u>. The three proposed analytical techniques were evaluated in the following general manner. Six waste types were identified as representing a typical range of waste handled by TSDF. These waste types were single-phase dilute aqueous waste, multiphase aqueous waste, aqueous sludge waste, organic sludge waste, organic waste, and solid waste. Six synthetic wastes were prepared to represent the six waste types.

Each synthetic waste contained varying concentrations of nine organic compounds chosen to represent different chemical classes with a range of physical characteristics. Two chlorinated compounds were chosen: methylene chloride, a chloroalkane with a very high vapor pressure, and chlorobenzene, a halogenated aromatic compound with a much lower vapor pressure. Three hydrocarbons were chosen: isooctane, an alkane with a high vapor pressure; toluene, an aromatic with a lower vapor pressure; and naphthalene, a polynuclear aromatic with a low vapor pressure. Three oxygenated hydrocarbons were chosen: 2-butanone, a ketone with a high vapor pressure; 1-butanol, an alcohol with a high vapor pressure; and phenol, an aromatic alcohol with a low vapor pressure. One nitrogen-containing organic compound was chosen: pyridine, an aromatic amine with a medium vapor pressure. The actual volatilities and relative volatilities of these compounds depend on the waste matrix and the environmental conditions.

The three separation techniques were evaluated under a variety of operating conditions. These conditions include batch steam distillation with a distillate volume varying from 1 percent to 40 percent of the total waste volume (1 to 40 percent boilover); purge and trap at 25 °C and 90 °C with purge volumes varying from 8 to 49 times the waste volume; and equilibrium headspace at 25 °C, 50 °C, 75 °C, and 90 °C. Each of the six synthetic wastes was tested under each set of conditions in triplicate, for a total of 54 tests.

The percent recovery for each compound from each waste was determined as a function of some physical parameter of the technique's operating conditions. Percent recovery is defined as the fraction of the initial amount of a compound added to a waste recovered in the distillate, charcoal traps, or headspace after separation from the waste. The variable parameter was one that controlled the degree of severity of the separation process.. For example, temperature was varied for headspace analysis, a combination of temperature and purge volume was varied for elevated temperature purgeand-trap, and volume of distillate or boilover was varied for batch steam distillation. Because a recovery profile was generated for each technique's set of operating conditions, a matching of the recovery from a specific technique and set of operating conditions with the predicted volatile emissions from a source category or type could be attempted at a later date. The recovery profile also allowed a single technique to be evaluated as a way to test several different waste treatment technologies. For example, the recovery for steam distillation with a boilover of 10 percent may match the emission potential of a surface impoundment; however, a steam distillation of 20 percent may be needed to match the emission potential of a land farm.

G.1.2.2 <u>Separation Technique Evaluation</u>. The batch steam distillation evaluation consisted of distilling 250 to 500 mL of synthetic waste or waste plus water, with water being added if the waste matrix were not aqueous. Condensate fractions were collected and analyzed at different points during the distillation. The waste's pH was initially made basic and then acidic after 20 percent of the sample had been removed. In addition to the condensate fractions, the vapors leaving the distillation apparatus were collected in a Tedlar bag, and the condenser was rinsed with solvent to remove solids and adsorbed organics.

The purge-and-trap technique initially purged approximately 7 mL of waste suspended in 18 mL of water. The waste was buffered at a pH of 8 and purged for 10 min at 25 °C and a flow rate of 20 mL/min. The organics removed were trapped on charcoal-adsorbent traps. The temperature was then raised to 90 °C, and the waste was purged for another 10 min. Finally, the

waste was purged a third time for 40 min, for a total purge time of 60 min. The adsorbent traps were changed after each purge step, extracted with a mixture of carbon disulfide and acetone, and analyzed.

For the headspace analysis, 10 g of synthetic waste was added to a 4-oz (115-mL) glass jar sealed with a Teflon-coated septum. The jar was placed in a constant temperature bath and allowed to equilibrate for 1 h. A volume of the headspace was then removed and analyzed. A separate sample was prepared for each temperature.

After testing each technique, it was confirmed that the recoveries varied widely between techniques, varied predictably with separation parameters, and varied with compound class.

The highest recoveries in all cases were achieved with steam distillation. As one would expect, recoveries increased with the amount of distillate boiled over. For most waste types, the bulk of the organic compound was recovered before 10 percent boilover. The water-soluble compounds with the lowest vapor pressures (phenol and pyridine) were the only compounds still being recovered in significant amounts after 10 percent boilover.

The purge-and-trap technique obtained the next highest recoveries. Very little of the water-soluble compounds was recovered at 25 °C. Increasing the temperature to 90 °C drastically increased the recovery for water soluble compounds 2-butanone, 1-butanol, and pyridine. Phenol was never recovered to any extent with this technique. The nonpolar compounds were recovered completely either at 25 °C or after 10 min at 90 °C, except for naphthalene whose recovery was generally low (especially in organic waste).

The headspace analysis obtained the lowest overall recoveries during the evaluations. An increase in recovery was found for all waste between the 25 °C, 50 °C, and 75 °C headspace analysis; however, most of the waste results showed little or no increase in recovery between 75 °C and 90 °C. In general, the recoveries for the organic waste were 5 to 10 times lower than for the other waste types. Like the purge-and-trap data, the watersoluble compounds were not recovered at 25 °C. Recovery of phenol was very low for most of the waste types even at 90 °C.

The general trend found between waste types for all three techniques was that the organic matrix waste retarded the removal of the nonpolar compounds and required more severe separation parameters to remove the same percentage as in an aqueous waste. Recovery of polar compounds from an organic matrix was slightly higher than from an aqueous matrix. For the steam distillation, recoveries were higher for the solid matrix than for all other waste forms, except for the multiphase waste. Although the multiphase liquid waste gave the highest overall recoveries for both the steam distillation and the headspace techniques, it gave the second to the lowest recoveries for the purge-and-trap technique. The headspace recoveries for a solid waste were lower than for the aqueous waste and higher than for the organic waste. For the purge-and-trap evaluation, the lowest recoveries were found for the solid waste.

Several general trends were also found for compound classes during all the technique evaluations. The compounds with lowest solubility were the first to be removed. Thus, the nonpolar compounds were generally the easiest to recover because most of the waste types either contained water or were mixed with water before testing. Vapor pressure appeared to have little influence, with naphthalene being recovered more easily than methylene chloride for many wastes. In organic waste, however, a direct relationship existed between vapor pressure and removal efficiency for nonpolar compounds. Of all the polar compounds, the two compounds known to dissociate appreciably in water (phenol and pyridine) were the most difficult to recover. Recoveries for all the polar compounds increased in organic waste types compared to the aqueous waste types.

Repeatability for each technique was evaluated by testing each synthetic waste in triplicate. By using the relative standard deviation (RSD) of the percent recovery for each compound at each point in a test, an estimate of the laboratory variability was made. The RSD of the final recoveries for the steam distillation ranged from 10 percent to 25 percent, with the greatest RSD found for the dilute aqueous waste where concentrations were the lowest. The variability for recoveries of individual compounds at points during the distillation were slightly higher than the variability at the 40 percent boilover.

Variability of the purge-and-trap recoveries was greater than that for steam distillation, with a range of 5 to 55 percent RSD for recoveries at 90 °C after a 60-min purge time. Unlike the variability of steam distillation, variability of the intermediate recoveries for the purge-andtrap technique were lower than the variability of the recoveries after a 60-min purge at 90 °C, and the waste form with the highest concentration (multiphase aqueous waste) showed the greatest variability in recoveries. Even so, the compounds with the lowest recoveries consistently had the highest variabilities.

The headspace technique provided the most consistent results. Variability for most of the recoveries was below 10 percent. Recoveries for the test at 25 °C showed the greatest variabilities. Solid waste showed the greatest variability of the waste types because of the low recoveries found. The polar compounds showed the highest variability, which again is a result of the low recoveries found for the compounds using the headspace technique.

G.2 MONITORING SYSTEMS AND DEVICES

Because of the wide variability and inconsistency of both the physical and chemical characteristics of most waste process streams, no continuous monitors for VO are likely to be available. Continuous monitors available to monitor proper operation and maintenance of control systems will be discussed after identification of potential control systems.

G.3 EMISSION TEST METHOD

At this time, no recommendations can be made regarding a compliance test method because the objective of such a test method has still not been fully defined and because of the shortcomings found in all the techniques during the laboratory evaluation. What follows is a discussion and comparison of these techniques, as well as the current work and planning being conducted to establish an acceptable compliance test method. Each technique was compared earlier with regards to recovery efficiency and repeatability. What was not mentioned are the problems and practical considerations of each technique.

Using percent recovery data alone to compare the techniques is not very useful for several reasons. The expected percent recovery for each compound from each waste treatment technology has not been determined, so the desired recovery efficiency is unknown. Another problem is that the percent recoveries calculated during the evaluation may not always represent what was removed from the waste. For certain waste types, the initial waste concentration and the final waste residue concentrations were determined. From these numbers, the percent removal could be calculated and compared with the percent recovered. In the case of the steam distillation test, a consistent discrepancy was found between the amount removed and the amount recovered, with the mass balance for nonpolar compounds showing a loss from the system. Similar problems were encountered with the purge-and-trap evaluation. The apparent loss of VO during the test could be a result of volatile loss during sample preparation, storage, and handling, or it could be a result of leakage from the apparatus or loss during measurement.

Experiments were conducted with two waste types to determine the volatile loss of the nine compounds during waste preparation, storage, and handling prior to the separation step. The results indicate that for the dilute aqueous waste only isooctance is significantly lost during preparation and storage whereas significant amounts of seven of the nine compounds are lost during handling. No loss was found from the organic waste during preparation, storage, or handling. Because losses were detected before the separation step with the synthetic waste, the better compliance test would minimize the number of sample handling steps. Of the techniques evaluated, headspace required the fewest handling steps.

Leaks from the test apparatus were more difficult to evaluate quantitatively. Leaks were detected from the steam distillation apparatus with a portable organic analyzer, but they could not be quantified. For steam distillation, several apparatus configurations and sealing materials were compared, and the measured loss remained constant. This strongly suggests that leakage from the apparatus is a minor source of loss. The technique with the simplest apparatus would be expected to have the least potential for leakage; again, the headspace technique best fits that description

Measurement losses could result from sample collection, storage, and handling of the collected volatiles after the separation step, calibration errors in the analysis, or matrix interferences during the analysis. A study is currently being conducted to determine which (if any) of these possible errors could be contributing to compound loss for the steam distillation technique. The condensate collection technique is being changed to determine if the recovery is affected by the way the samples are collected, handled, and stored. Matrix spike studies are also being performed to determine if any matrix effects are occurring during condensate analysis. Because measurements taken for the headspace technique only require a simple gaseous injection, measurement error would be minimized.

From the standpoint of cost and complexity, the headspace technique appears to be the best choice as a candidate compliance test method. The purge-and-trap technique would be second best, with steam distillation a close third. As the evaluation results show, removal efficiency is inversely proportional to the cost and complexity of the technique. Although the headspace technique may be easy to perform and it may provide good measurement of the removed organics, its low removal efficiencies may prevent its use for waste facilities where emission potential may demand a more severe separation technique.

A fourth technique is currently being evaluated that will combine some of the operational ease and simplified measurements of the purge-and-trap technique with the more severe separation of the steam distillation technique. This method is a modification of the California Air Resource Board Method 401 gravimetric purge-and-trap. The basic principle to its operation is to suspend the waste in an organic matrix (dioctylphthalate) and purge with a high purge flow rate (15 L/min) at approximately 100 °C.

The original method would require measuring the mass gain of a charcoal trap used to collect the VO. The proposed compliance method would lower the detection limit and increase the volatility range by measuring the removed VO with a continuous total organic analyzer or by analyzing the charcoal trap's solvent extract.

Once the gravimetric purge-and-trap technique is evaluated and the required removal efficiency is known, the best candidate method or methods will be chosen. An optimization study will be performed, followed by a real waste evaluation. Feasibility of method automation and simplification will be investigated before the method is released in its final form. COSTING OF ADD-ON AND SUPPRESSION CONTROLS

APPENDIX H

APPENDIX H

COSTING OF ADD-ON AND SUPPRESSION CONTROLS

The purposes of this appendix are (1) to document the general approach used in developing detailed cost estimates for add-on emission control technologies that could be applied to control air emissions from hazardous waste treatment, storage, and disposal facilities (TSDF), (2) present a specific example of add-on control cost development, and (3) summarize the add-on control costs. The model units (presented in Appendix C) developed for each TSDF waste management process served as the basis for the cost analysis. Detailed cost estimates were made for the types of add-on control devices listed in Chapter 4.0 (Table 4-2). The total annual cost for each control technology has been divided by the appropriate model unit throughput to yield an estimated cost per megagram of waste managed. The ultimate use of these costs is to estimate the nationwide cost of controlling organic air emissions from TSDF. This same costing approach described here was used to develop detailed cost estimates for the organic removal processes presented in Appendix I. The cost of incineration processes was made using a different procedure, which is described briefly in Appendix I.

The bases for the costing method developed are (1) an EPA guidance manual on estimating the cost of air emission controls,¹ (2) a textbook, <u>Plant Design and Economics for Chemical Engineers</u>,² and (3) a series of articles in <u>Chemical Engineering</u> magazine.³⁻⁸ These sources identified the total capital investment, annual operating cost, and total annual cost (i.e., annualized cost) as the key elements of a cost estimate. Section H.1 describes how each of these key elements was costed.

A specific example of the cost approach, the control of organic air emissions from an aerated, uncovered hazardous waste treatment tank via a fixed roof vented to a fixed-bed carbon adsorber is presented in

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Section H.2. All costs are expressed in January 1986 dollars. A specific example of the cost approach for the organic removal processes is provided in Section I.2 of Appendix I.

A summary of the total capital investment, annual operating cost, and total annual cost for add-on controls applied to selected model units is presented in Section H.3. These results are based on detailed cost estimates for each add-on control device found in the design and cost document prepared as part of the TSDF project docket.⁹

H.1 COSTING APPROACH

H.1.1 Data

For each detailed cost estimate, three cost tables are provided. The first table lists the major equipment items associated with the control system and the capital cost of each item. The second table lists any required auxiliary equipment and their costs plus direct and indirect installation charges. The third table lists the direct and indirect annual operating cost and the total annual cost.

H.1.2 Total Capital Investment

The total capital investment for a control device includes all costs required to purchase equipment, the costs of labor and materials for installing the equipment (direct installation charges), costs of site preparation and buildings, and indirect installation charges. Items normally included in the direct installation charges are foundations and supports, erection and handling of equipment, electrical work, piping, insulation, and painting. Indirect installation charges include costs for engineering, construction and field expenses, contractor fees, startup and performance testing, and contingency expenses.¹⁰

The major equipment items that constitute the control system and that are necessary for its installation were costed for each model unit listed in Appendix C. The first table of each set of cost tables presents the major equipment items. The purchase cost, materials of construction, and size of each item were obtained from vendor data, handbooks (such as Perry's <u>Chemical Engineers' Handbook¹¹</u>), the literature, and plant trip reports from numerous operating commercial facilities. In general, the purchase cost is "F.O.B.," meaning no taxes, freight, or installation

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charges are included. However, in some instances, purchase cost data obtained from a vendor or other source does include taxes, freight, or installation charges.

All purchase costs are expressed in January 1986 dollars. If the cost data obtained represent the cost at a different time, escalation factors are used to convert to 1986 dollars. Table H-1 presents the cost escalation factors used in this study. The sum of the purchase costs for the major equipment items is equal to the base equipment cost.

Once the base equipment cost is determined, the purchased equipment cost can be computed. The purchased equipment cost includes the cost for auxiliary equipment (e.g., pumps and ductwork), instrumentation, freight, and sales tax.¹³ Costs for pumps and ductwork are developed based on information obtained from vendors or the literature and, when necessary, on engineering judgment. If the costs for pumps and ductwork are found to be a large fraction of the purchased equipment cost, they are presented as a separate item in the major equipment list.

The costs for instrumentation, freight, and sales tax are factored from the sum of the base equipment cost and the auxiliary equipment cost. The factors used are listed in Table H-2.14

The direct and indirect installation charges for each control device are factored directly from the purchased equipment cost and are based on such considerations as: (1) whether the control device is delivered as a packaged unit or requires field assembly, (2) the availability of utili ties, and (3) whether the equipment is to be outside or enclosed. The cost of site preparation and buildings are based on information obtained from vendors and other sources such as cost manuals.¹⁵ The sum of the purchased equipment cost, direct installation charges, and indirect installation charges are equal to the total capital investment.

H.1.3 Annual Operating Costs

The annual operating cost for a control consists of direct and indirect charges less any recovery credits. Recovery credits result from the recovery of organics from the waste through the use of organic removal processes such as steam stripping, batch distillation, and thin-film evaporation equipped with control devices such as condensers, or fixed-bed

Year	Cost multiplier ^a
1981 - 1986	1.245
1982 - 1986	1.095
1983 - 1986	1.036
1984 - 1986	1.027
1985 - 1986	1.008

TABLE H-1. COST ADJUSTMENT MULTIPLIERS¹²

^aThe cost adjustment multipliers were obtained from the <u>Chemical Engineering</u> magazine plant cost index and were used as necessary in the costing process to adjust costs to January 1986 dollars.

TABLE H-2. FACTORS USED TO ESTIMATE PURCHASED EQUIPMENT COSTS

Item	Value (* BEC + auxiliary equipment) ,
Instrumentation	10.0
Freight	5.0
Sales tax	3.0

BEC = Base equipment cost.

regenerable carbon adsorption. Recovery credits can be based on the value of specific chemicals recovered or the energy value of the recovered organics. Energy recovery credits have been selected for nationwide cost estimates because they are consistent with the existence of an established waste processing industry sector that produces "waste fuels." Also, it would be more difficult to establish the true value of specific chemicals recovered because of the unknown costs to separate them from impurities.

Direct operating charges include all costs for raw materials; utili ties; operating, supervisory, and maintenance labor; replacement parts; waste disposal (spent carbon or spent carbon canisters, for example); and maintenance materials. The indirect operating expenses include overhead, property taxes, insurance, administrative charges, and capital recovery.¹⁶

The annual cost for raw materials, utilities, and waste disposal are based on estimated consumption or discharge rates multiplied by appropriate unit costs. Generally, add-on controls do not require raw materials. Utilities include electricity, steam, water, and auxiliary fuel. Waste disposal costs include effluent and sludge generated from venturi scrubbers, spent activated carbon, and hazardous ash from incinerators.

Operating labor costs are estimated by multiplying the annual hours of operation (based on typical TSDF industry practices) by the operator wage rate. The labor rate for operators is also used for organic control activities that do not include actual devices, such as response to waste spills. Supervisory labor costs are estimated as 15 percent of the operating labor requirement.¹⁷ Maintenance labor costs are determined by multiplying the estimated annual number of maintenance hours required by the maintenance labor rate. Because maintenance laborers are generally more skilled than control operators, a 10-percent wage premium is included in the labor rate.¹⁸ Note that these are base labor rates, which do not include fringe benefits, worker's compensation, pension, or Social Security. These factors are included in the estimation of overhead.

Maintenance materials typically include items such as oil, lubricants, and small tools. These costs are estimated as 100 percent of maintenance labor.19 Replacement parts include items such as activated carbon for carbon adsorbers and filter bags for baghouses. Typically, these expenses are large and are incurred one or more times during the useful life of a control. The annual cost for replacement parts is estimated as a function of the initial parts costs, replacement labor costs, the life of the parts, and the assumed interest rate.²⁰ The annual cost for replacement parts is estimated as:

$$CRCp = (Cp + Cp1) * CRFp$$

where

CRCp = annualized cost for replacement parts, \$/yr

Cp - initial cost for replacement parts, \$

Cpl = replacement labor costs, \$

CRFp = capital recovery factor for the parts

 $= \frac{i(1+i)n}{(1+i)n-1}$

i = annual interest rate

n = useful service life of the replacement parts.

As stated earlier, overhead includes such items as fringe benefits, workmen's compensation, pension, and Social Security. Also included in the estimation of overhead are fixed costs for items such as plant security, parking, and landscaping. Because it is often difficult to estimate these items individually, overhead costs generally are factored as a percentage of total labor and maintenance material costs. A value of 60 percent is used to estimate the overhead expenses associated with a control device.²¹ Property taxes, insurance, and administrative charges are estimated as 1, 1, and 2 percent, respectively, of the total capital investment.²²

Capital recovery is the annualized recovery of the total capital investment over the useful service life of the control. Capital recovery was determined as: CRCs = CRFs * (TCI - Cp)

where

CRCs = capital recovery for the control, \$/yr CRFs = capital recovery factor for the control $= \frac{i(1+i)^n}{(1+i)^{n-1}}$

TCI = total capital investment, \$

i = annual interest rate

n = useful service life of the control, yr.

The last term on the right side of the equation, Cp, accounts for replacement parts purchased during the useful service life of the control. H.1.4 Total Annual Cost

The total annual cost (i.e., annualized cost) for a control is the sum of all direct and indirect annual operating costs less any recovery credits (recovery credits were discussed in Section H.1.3). Table H-3 presents the unit costs for utilities and labor and the interest rate used in the example cost estimate that follows.

H.2 DETAILED EXAMPLE COST ANALYSIS FOR A FIXED ROOF VENTED TO A FIXED-BED CARBON ADSORBER APPLIED TO AN UNCOVERED, AERATED TREATMENT TANK

H.2.1 Introduction

To illustrate the cost approach outlined in Section H.1, an example cost analysis for controlling a TSDF treatment tank is presented in this section. The control technology applied is a fixed roof vented to a fixedbed carbon adsorber. Discussions of the applicability and performance of fixed roofs and fixed-bed carbon adsorbers can be found in Chapter 4.0, Sections 4.1.2.1 and 4.2.2, respectively. Similar analyses were performed for all of the types of control technologies listed in Table 4-2, and the results are contained in the design and cost document that presents the details of cost estimating for potential TSDF controls such as suppression controls. This cost document provides sets of cost tables for each model

Item	Unit price, 1986 \$	Reference
Utilities		
Electricity Steam Process makeup water	0.0463 (\$/kWh) \$7.19 (\$/Mg) \$0.04 (\$/m ³)	23,24,25 26,27,28 29
Labor .		
Operators Maintenance	12.00 (\$/h) 13.20 (\$/h)	30 31,32
Capital recovery		
Interest rate (real)	10*	33

TABLE H-3. UTILITY RATES, LABOR RATES, AND INTEREST RATE USED IN EXAMPLE COST ESTIMATE^a

^aThese unit costs were obtained from current information sources and are used to estimate the cost of individual elements of potential TSDF controls. unit, process flow diagrams, material balances, energy consumption, sample calculations, and other details of potential TSDF control cost estimating.³⁴

H.2.2 Model Unit

An uncovered, diffused air hazardous waste treatment tank with a capacity of 108 m³ (model unit TO1G) was selected as the unit of analysis to develop the detailed cost estimate. This size was selected from the range of sizes identified in the Westat Survey³⁵ of hazardous waste generators and TSDF. Uncovered, diffused air tanks typically are cylindrical steel structures. The model treatment tank parameters are summarized in Table H-4. Additional details of this model unit can be found in Appendix C.

H.2.3 Emission Estimates

Under normal operating conditions, organic emissions occur from the waste surface of diffused-air waste treatment tanks as a result of air being sparged into the bottom of the tank and leaving at the top. The sparged air strips organics from the waste as the air bubbles rise through the liquid, and the air leaving the waste surface is enriched with organics and water vapors. This loss of organics to the air constitutes the uncontrolled emissions to which the emission control system is applied.

Estimates of annual uncontrolled emissions from the model diffused-air treatment tank described above were determined using the emission models and model unit parameters described in Appendix C of this document. Table H-5 presents the estimated uncontrolled organic emission for two model waste compositions likely to be found at TSDF aerated treatment tanks. For a detailed discussion on the selection of the model wastes and their compositions, refer to Appendix C.

H.2.4 Emission Control System

As shown in Figure H-1, the major emission control system equipment consists of a fixed roof, vent piping, two fixed-bed carbon adsorber units, and a pressure and vacuum relief valve. The overall emission reduction achieved by the system is estimated to be 95 percent, as discussed in Chapter 4.0 of this document.³⁶ This estimated overall emission reduction is achieved by a combination of the capture efficiency of the fixed-roof, estimated to be 100 percent, and the control efficiency of the carbon adsorber, estimated at 95 percent.

TABLE H-4. MODEL UNIT PARAMETERS FOR AN UNCOVERED, DIFFUSED-AIR TREATMENT TANK (TO1G)^a

Volume -	108 m ³
Surface area	26.4 m ²
Height	2.9 m
Throughput	235,000 Mg/yr

^aThis model unit is one of several models of treatment and storage tanks that were defined for the purpose of estimating emissions, emission control costs, and emission reductions for tanks at TSDF. These models reflect differences in size, waste throughput, and other characteristics of tanks found at TSDF.

TABLE H-5. ESTIMATED UNCONTROLLED EMISSIONS FROM AN UNCOVERED, DIFFUSED-AIR TREATMENT TANK (TO1G) HANDLING TWO DIFFERENT MODEL WASTES

Waste form ^a	Uncontrolled emissions, ^b Mg/yr				
Dilute aqueous	870				
Aqueous sludge/slurry	130				

^aModel waste compositions are presented in Appendix C.

^bEmissions from the dilute aqueous waste are greater than emissions from the aqueous sludge/slurry (even though the aqueous sludge/slurry has a much higher total organic content) because of the higher volatility of the organic compounds in the model dilute aqueous waste.



Figure H-1. Schematic diagram of dual, fixed-bed gas-phase carbon adsorption system with steam regeneration.

Parameters used to determine the carbon bed size are: (1) volumetric flow rate to the adsorber (dependent on the explosive limits for the organics in air), and (2) inlet and outlet organic mass loadings, adsorption time, and working capacity of the carbon. 3^7 Carbon working capacities vary with the specific compounds being adsorbed. Likewise, the lower explosive limit (mixture of the organic[s] in air) is compound-dependent. Because of the wide variety and large number of compounds for which carbon adsorption control costs are needed, a generic approach to carbon adsorption system design was developed for use in estimating nationwide impacts. The carbon bed size for the example presented here was determined using procedures presented in Reference 37 and average or mean values for lower explosive limit and carbon working capacity.³⁸ In general, for sizing the carbon beds, volumetric flow rate was specified to maintain the organic concentration at 25 percent or less of the lower explosive limit, and the adsorption cycle time was maintained between 8 and 12 hours. A dilute aqueous waste composition (dilute aqueous-1) described in Appendix C was used in the example cost analysis.

H.2.5 Cost Analysis

Tables H-6 through H-8 present the estimated base equipment cost, total capital investment, total annual cost, and annual operating cost for a fixed roof vented to a fixed-bed carbon adsorber.

The major equipment items required for the system are listed in Table H-6. These items include a fixed roof, carbon adsorbers, granular activated carbon, pressure and vacuum relief valves, and other process equipment such as ducting. The purchase costs, excluding taxes and freight for all items, were obtained from vendor data^{75,76} and literature sources.^{77,78} The total base equipment cost for the system was estimated to be \$70,700.

The purchased equipment cost, direct and indirect charges, and total capital investment are shown in Table H-7. Pumps, ductwork, and instrumentation are included as other equipment in the major equipment items for this system. The costs for freight and sales tax were factored from the base equipment cost as discussed earlier. The purchased equipment cost for this system is estimated at \$76,400.

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		Materials of	Purchase	
Item (number)	Size	construction	\$	References
Tank cover				
Fixed-roof ^b	27 m ²	Aluminum	11,500	39,40
Pressure/vacuum relief valve	76 mm diameter	Stainless steel	1,600	41
<u>Carbon</u> adsorber				
Adsorbers (2)		Stainless steel	27,400	42,43
Carbon	3,538 kg ^c @\$4 kg	Granular activated carbon	14,000	44,45
Other process equipment ^d			16,200	46,47
Base equipment cost		Tank fixed	13,100	
(BEC)		carbon ad-	57,600	
		sorber Total	\$70,700	

TABLE H-6. MAJOR EQUIPMENT ITEMS NEEDED TO INSTALL A FIXED ROOF VENTED TO A FIXED-BED CARBON ADSORBER ON AN UNCOVERED, DIFFUSED-AIR TREATMENT TANK (TO1G)^a

^aThis table lists the major items of equipment needed to control air emissions from the model tank. The necessary number of each item, the cost of each item, and the source of information used are identified. Costs are in January 1986 dollars. Costs are for dilute aqueous waste. Waste forms and their compositions are presented in Appendix C.

^bThe fixed roof is a sealed unit with an opening for ducting to the carbon adsorber. Aeration is assumed to be provided by an existing diffused-air system.

^CAirflow is sufficient to maintain contaminant concentrations below 25 percent of the lower explosive limit.

^dOther process equipment for the fixed-roof tank includes ducting and safety screen for venting off-gases from the tank. Other process equipment related to the carbon adsorber includes fan, condenser, decanter, pumps, piping, and instrumentation. Process equipment costs are based on Reference 25, which suggests a cost of 39 percent of the total cost for adsorbers and carbon.

Item	Value			Cost, \$		References
Direct equipment costs			Cover	Adsorber	Total	
Base equipment cost (BEC)			13,100	57,600	70,700	
Pumpsb			ÓØ	ÓØ	Ó	
Ductwork ^b			Ø	Ø	Ø	
Instrumentation ^c			Ø	Ø	Ø	·
Sales taxes and freight	8% (BEC + in	str.)	1,050	4,610	5,660	48
Purchase equipment cost (PEC)			14,200	62,200	76,400	
Direct installation costs	Cover	Adsorber				
Foundations and supports		8% of PEC	Ø	4,980	4,980	49
Piping			Ø	Ø	Ø	
Electrical		4% of PEC	Ø	2,490	2,490	5Ø
Handling and erection		14% of PEC	Ø	8,720	8,720	51
Painting		1% of PEC	Ø	62Ø	620	52
Insulation		1% of PEC	Ø	62Ø	62Ø	53
Site prep. and building			Ø	500	500	54
Indirect installation costs						
Engineering	5% of PEC	10% of PEC	710	6,230	6,940	55, 56
Construction and field expenses	10% of PEC	5% of PEC	1,420	3,110	4,530	57, 58
Construction fee		10% of PEC	Ø	6,230	6,230	59, 6Ø
Startup and testing	2% of PEC	3% of PEC	28Ø	1,87Ø	2,150	61, 62
Contingency	3% of PEC	3% of PEC	42Ø	1,870	2,290	63, 64
Total capital investment (TCI)			17,000	99,500	116,000	

TABLE H-7. TOTAL CAPITAL INVESTMENT FOR A TANK COVER VENTED TO A FIXED-BED CARBON ADSORBER APPLIED TO AN UNCOVERED, DIFFUSED-AIR TREATMENT TANK (TØIG)^a

^aThis table shows the estimated direct and indirect installation costs associated with the emission control system. These installation costs are combined with equipment costs to obtain the estimated total capital investment required.

^bPumps and ductwork are included as other equipment in major equipment items.

CInstrumentation costs for carbon adsorber are included as other equipment in major equipment items.

Item	Value or unit price	Annual consumption	Annual cost,b \$	References
Direct annual costs				
Raw materials				
Utilities				
Electricity	\$0.0 463/kWh	37,100 kWhC	1,720	65
Steam	\$7.19/Mg	2,890 Mg	20,800	66
Cooling water	\$0.04/m ³	270,000 m ³	10,700	67
Labor				
Operator	\$12/h ^C	550 hr/vr	6.600	68
Supervision and	15% of dir. labor	,5	990	69
administration				
Maintenance	\$13.2/hd	550 hr/yr	7,26Ø	7Ø
Maintenance materials	100% of maint. labor		7,26Ø	71
Replacement parts				
Carbon replacement ^e	\$4/kg Replacement labor at \$0.11/kg 5 yr life, 10% interest	Ø.2638 x initial carbon cost plus replace ment labor	4,100	72
Indirect annual costs				
Overhead	60% (Lab. + maint. mat.)		13,300	73
Property taxes, insurance, and administrative charges	4% of TCI		4,66Ø	74
Capital recovery	10% at 10/yr (excluding initial carbon cost)		16,700	
Recovery credits ^d			Ø	
See notes at end of table.				(continued)

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TABLE H-8. ANNUAL OPERATING AND TOTAL ANNUAL COST FOR A FIXED ROOF VENTED TO A FIXED-BED CARBON ADSORBER APPLIED TO AN UNCOVERED, DIFFUSED-AIR TREATMENT TANK (TØ1G)^a

TABLE H-8 (continued)						
Item	Value or unit price	Annual consumption	Annual cost, ^b \$	References		
Total annual cost	Direct + indirect costs - credits		94,000			
Annual operating cost (AOC)	Direct + indirect costs - capital recovery - credits		77,400			
Throughput	Mg/yr	235,000				
Cost/throughput	\$/Mg		0.40	<u></u>		

TCI = Total capital investment.

^aThis table presents example annual operating costs and total annual costs for an emission control system applied to a tank handling dilute aqueous waste. Costs for other waste forms would be calculated similarly Differences in costs would be due to differences in the size of the carbon adsorber. Totals may differ due to rounding.

^bJanuary 1986 dollars.

Carbon adsorber: 102 kWh/day, 365 days/yr

 d Recovered organic from the carbon adsorber is recycled to the treatment tank.

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The direct installation charges include items related to installing the adsorber, e.g., foundations and handling and erection. There are no separate direct installation charges for the fixed roof because the vendor supplied data only for the total installed cost. The total direct installation charges are 29 percent of the purchased equipment cost for the carbon adsorbers. Indirect installation charges include engineering, construction and field expenses, construction fees, startup and testing, and contingency expenses. These charges are 29 percent of the total purchased equipment cost. Summing the purchased equipment cost and the direct and indirect charges gives an estimated total capital investment of \$116,000.

Table H-8 presents the direct and indirect annual operating cost, total annual cost, and cost per megagram of throughput for the dilute aqueous-1 model waste for the fixed-bed carbon adsorber. Utility costs, labor rates, and interest rate used are from Table H-3.

Indirect annual costs include overhead; property taxes, insurance, and administrative charges; and capital recovery. As stated earlier, overhead was estimated to be 60 percent of all labor costs plus maintenance material costs. Capital recovery of the total initial investment (minus the initial cost of carbon) is based on an estimated service life of 10 years and a real interest rate of 10 percent. Property taxes, insurance, and administrative charges were factored at 4 percent of the total capital investment.

The total annual operating cost is equal to the direct plus indirect annual costs less the capital recovery and any credits. As shown in Table H-8, the annual operating cost is \$77,400 for controlling emissions from the dilute aqueous-1 model waste.

The total annual cost for a fixed-bed carbon adsorber was determined as the direct plus indirect annual costs less any credits. The total annual cost is \$94,000 for an adsorber controlling emissions from the dilute aqueous-1 model waste.

The annual cost per megagram of throughput was determined by dividing the total annual cost by the amount of waste treated. In the model unit used in the example cost analysis, annual throughput is 235,000 Mg, which results in a unit cost of \$0.40 per megagram of waste treated. Based on cost estimates for two model waste compositions, composition differences between the model wastes cause a significant difference in the costs of the control system. For the example system controlling air emissions from the dilute aqueous-1 model waste, total annual costs are \$94,000 and the cost per megagram of waste treated is \$0.40. On the other hand, a system designed to control emissions from the aqueous sludge/slurry model waste has a total annual cost of \$64,000 and a cost per megagram of waste treated of \$0.27. The lower cost for the aqueous sludge/slurry is brought about by the lower uncontrolled emissions from that model waste (see Table H-5), which, in turn, results in smaller carbon beds in the control system. The smaller carbon beds have both lower capital costs and lower operating costs.

H.3 SUMMARY OF CONTROL COSTS

To determine the potential nationwide cost of controlling organic emissions from hazardous waste TSDF, model unit costs were developed for each of the add-on controls listed in Table 4-3. The model units used in the costing exercise are presented in Section C.2 of Appendix C.

A summary of the control costs for each add-on control as applied to one model unit is presented in Table H-9. In this table, total capital investment, annual operating cost, total annual cost, and cost per megagram of waste treated for each control are given. Also listed are the assumed efficiency, the service life of the control device, and the quantity of waste treated. The ultimate use of the costs presented in Table H-9 is to estimate nationwide impacts.

For each waste management process (e.g., an aerated surface impoundment), a range of model unit sizes that span the range of process sizes found at TSDF was used to develop emission and cost estimates that reflect current industry operating practices. However, because sitespecific characteristics of hazardous waste management units throughout the country are unknown, a "national average model unit" was developed to represent each type of waste management process. Statistical data were available to describe the national distribution of waste management unit

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TSDF source		Eff	ect on emission:	s, ^b %		Model unit ^d throughput,	Total capital®	Annual operating ^e	Total annual®	Annual cost per unit throughput,
(model unit)	Control device	Capture	Suppression	Control	Waste form ^C	Мg/уг	investment, \$	cost, \$	cost, \$	\$/Mg
Covered	Vent to carbon canister	100		95.Ø	Dilute aqueous	3,330	1,050	87,400	87,600	26.4
storage tanks		100		95.0	Organic liquid	3,250	1,050	20,310	20,600	6.31
(\$020)		100		96.0	Organic sludge/slurry	3,900	1,050	47,000	47,200	12
		100		95.0	Aqueous sludge/slurry	4,100	1,050	7,940	8,100	1.98
		100		95.0	2-Phase aqueous/organic	3,850	1,050	38,600	38,700	10
	Internal floating roof ^f		74.0		Dilute aqueous	3,330	11,400	2,180	3,490	1.05
			61.0		Organic studge/slurry	3,900	11,400	2,160	3,490	0.09
			79.0		2-Phase aqueous/organic	3,850	11,400	2,160	3,500	Ø.91
Covered treatment tank (quiescent) (TO1E)	Fixed-bed carbon adsorption			95. Ø	ATT	27,700	73,300	38,600	60,400	1.82
Uncovered	Fixed-roof		87.5		Dilute aqueous	3,330	14,800	1,200	2,900	0.88
storage tanks			99.2		Organic liquid	3,250	14,800	1,200	3,000	Ø.91
(5021)			98.9		Organic sludge/slurry	3,900	14,800	1,200	2,900	0.75
. ,			98.2		Aqueous sludge/slurry	4,100	14,800	1,200	2,900	0.72
			93.6		2-Phase aqueous/organic	3,850	14,800	1,200	2,900	Ø.76
	Fixed-roof vented to	100	87.5	95.0	Dilute aqueous	3,330	15,900	88,600	90,500	27.2
	carbon canister	100	99.2	95.0	Organic liquid	3,250	15,900	21,500	23,400	7.22
		100	98.9	95.0	Organic sludge/slurry	3,900	15,900	48,200	50,200	12.8
		100	98.2	95.0	Aqueous sludge/slurry	4,100	15,900	9,100	11,100	2.7
		100	93.5	95.0	2-Phase aqueous/organic	3,850	15,900	39,800	41,700	10.8
	Fixed-roof with internal floating roof		95.Ø		All	3,330-4,100	24,500	2,980	5,800	1.43- 1.01
Uncovered treat-	Fixed roof vented to	100		95.0	Dilute aqueous	235,250	124,000	48,100	65,900	0.28
ment tank (aerated) (T01G)	fixed-bed carbon adsorption	100		95,0	Aqueous sludge/slurry	235,250	125,000	78,100	94,100	0.40
Surface impound- ment storage (quiescent) (S04C)	Floating membrane		85.0		ATT	49,140	67,000	6,890	18,200	0.33
	Air-supported structure	100		95.0	Dilute aqueous	49.140	249.000	64.600	102.000	2.07
	vented to fixed-bed	100		95.0	Aqueous sludge/slucry	49,140	311,000	93 200	137 000	2 78
	carbon adsorption	100		95.0	2-Phase aqueous/occanic	49,140	249.000	64.800	102,000	2.07
	2					,	,	,	,000	2.01
	· ·									· - ·

TABLE H-9. TOTAL CAPITAL INVESTMENT, ANNUAL OPERATING COST, AND TOTAL ANNUAL COST FOR ADD-ON AND SUPPRESSION CONTROLS APPLIED TO A TSDF SOURCE®

See notes at end of table.

(continued)
				TABL	E H-9 (continued)					
TSDF source (model unit)	Control device	Eff Capture	ect on emission Suppression	i,b % Control	Waste form ^c	Model unit ^d throughput, Mg/yr	Total capital® investment, \$	Annual operating® cost, \$	Total annual® cost, \$	Annual cost per unit throughput \$/Mg
Treatment impoundment (quiescent) (TO2D)	Air-supported structure vented to fixed-bed carbon adsorption	100 100 100		95.0 95.0 95.0	Dilute aqueous Aqueous sludge/slurry 2-Phase aqueous/organic	98,595 98,595 98,595	237,000 263,000 237,000	59,900 88,400 59,900	97,600 182,000 97,600	0.99 1.30 0.99
	Floating synthetic membrane				AII	98,595	57,000	6,890	15,800	0.16
Fixation pit (Å)	Change to mechanical mixer with baghouse and fixed-bed carbon adsorber	100		95.Ø	ATT	16,65 0	464 , 000	138,000	224,000	13.4
Fixation- mechanical mixer (A)	Vent to fixed-bed carbon adsorber	100		95.0	ATT	16,650	154,000	67,600	88,400	5.31
Drum or other container storage (SD1B)	Vent to carbon adsorption			95.0 95.0 95.0 95.0 95.0 95.0 95.0	Dilute aqueous Organic liquid Organic sludge/slurry Aqueous sludge/slurry 2-Phase aqueous/organic Organic-containing solid	450 440 610 560 440 800	39,900 40,100 39,000 40,100 40,100 39,600	12,000 12,000 12,000 12,000 12,000 12,000 12,000	18,400 18,500 18,300 18,500 18,500 18,500 18,400	41 42 30 33 42 23
Dumpster (S01C)	Dumpster cover		99.0 99.0		Aqueous sludge/slurry Organic-containing solid	16 24	150 150	40 40	64 72	4 3
Wastepile (SØ3E)	30-mil HDPE wastepile cover		2.2-98.4	3	ATT	116,500	6,480	2,470	4,660	0.04
Active landfill (D80E)	Daily earth cover		11.0		ATT	116,500	0	313,000	313,000	2.69
Closed landfill (D80H)	30-mil HDPE cover		2.2-98.0	3	AII	116,500	60,400	2,400	9,300	0.00
	100-mil HDPE cover		7.0-99.0	ذ	ALL	116,500	156,000	6,200	23,300	0.20
See notes at end	of table.								(c	ontinued)

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•				TABLE I	E H-9 (continued)			. . ,			
TSOF source (model unit)	Control device	Eff Capture	ect on emissions Suppression	b X Control	Wasto form ^c	Model unitd throughput, Mg/yr	Total capitale investment, \$	Annual operating ^e cost, \$	Total annual cost, \$	Annual cost per unit throughput, \$/Ng	
Tank and container loeding (drum loading)	Submarged loading	00	6 5. <i>0</i>		A11	39	390	20	70	0.15	
Equipment leaks (A)	Möüřyja jużbečřiou										
	Light liquid service9		70		A11		2 7 , 900	7,790	12,300		
	Heavy liquid serviceh		78	 i(:::	ALF	یے تئے یہ	27,000	1,700	8,100		

TSDF = Treatment, storage, and disposal facility.

-- = Not applicable.

^aThis table summarizes the costs of potential add-on and suppression controls to reduce TSDF air emissions.

^bA control device may affect emissions in any of three ways. It may capture (or contain) emissions and pass them to an emission control device; it may suppress emissions by containing them or reducing the rate at which they leave the source; or it may control emissions by destroying the organics or removing organics from a vent stream.

CFor initial model waste stream compositions, refer to Appendix C.

dDensities used to convert volumetric waste throughputs to mass throughputs were the following:

Dilute aqueous - Ø.999 kg/L Organic liquid - Ø.976 kg/L Organic sludge/slurry - 1.34 kg/L Aqueous sludge/slurry - 1/23 kg/L Two-phase aqueous/organic - 0.976 kg/L Organic-containing solid - 1.76 kg/L

^eJanuary 1986 dollars.

fEmissions and emission reductions vary with waste form as a result of the different concentrations and volatility of organics present in the model wastes used to represent the waste form.

9The model unit used as a basis for estimating cost contains 5 pump seals, 165 valves, 9 sampling connections, 44 open-ended lines, and 3 pressure-relief valves. Costs are a function of the number of each of these items in the waste management process.

hThe model unit contains the same equipment counts as described in note g, but only the sampling connections, open-ended lines, and pressure-relief valves are included in the inspection and maintenance program.

sizes, e.g., surface area of surface impoundments and tank volumes for storage tanks. These statistical size distribution data were used to develop weighting factors for each model unit size.⁷⁹ The costs (total capital investment and annual operating cost per megagram of waste throughput) for each model unit size were multiplied by the corresponding weighting factor. The sum of these products results in weighted cost factors for each national average model unit. The weighted cost factors were then compiled for use in estimating nationwide costs.

The data base used by the Source Assessment Model to estimate nationwide impacts identifies the waste streams and waste management processes of each TSDF. The weighted average costs were multiplied by the throughput for each waste management process at each TSDF. The waste throughputs were obtained from the TSDF Industry Profile, a collection of facility-specific data described in Appendix D. These costs are then summed over all waste management processes at all TSDF to obtain a nationwide cost estimate.

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APPENDIX I

COSTING OF ORGANIC REMOVAL PROCESSES AND HAZARDOUS WASTE INCINERATION

APPENDIX I

COSTING OF ORGANIC REMOVAL PROCESSES AND HAZARDOUS WASTE INCINERATION

Organic removal processes and hazardous waste incinerators provide alternatives to using add-on and suppression air emission controls at hazardous waste treatment, storage, and disposal facilities (TSDF). Removal or thermal destruction of organic compounds in a hazardous waste prior to disposal of the waste in a TSDF unit (e.g., surface impoundment, treatment tank, or landfill) will lower the content of volatile organics in the waste and, consequently, reduce the air emissions from the TSDF unit. The purpose of this appendix is to:

- Explain the methodologies used to estimate organic removal processes and incinerator control costs
- Present an example cost analysis for an organic removal process (steam stripping)
- Summarize organic removal processes and incinerator control costs presented in the document <u>Cost of Volatile Organic</u> <u>Removal and Model Unit Air Emission Controls for Hazardous</u> Waste Treatment, Storage, and Disposal Facilities.¹

I.1 COST ANALYSIS METHODOLOGIES

Cost analysis methodologies were developed to estimate the control costs for organic removal processes and incinerators. These costs include capital investment, annual operating cost, total annual cost (i.e., annualized cost), cost per quantity of hazardous waste processed, and cost per quantity of organic removed from the hazardous waste as a result of processing. All costs are expressed in January 1986 dollars.

Control costs are used for estimating the nationwide costs of implementing different potential TSDF control strategies. A recent survey

of the TSDF industry by EPA provided current data about the quantities of hazardous waste processed at each TSDF located in the United States (refer to Appendix D, Section D.2.1). To calculate the nationwide costs for using organic removal processes or incinerators to control TSDF air emissions, the costs per quantity of waste processed summarized in Section I.3 were incorporated into the Source Assessment Model (refer to Appendix D, Section D.1).

I.1.1 Organic Removal Processes

Control cost analyses were performed for four types of organic removal processes: (1) air stripping, (2) steam stripping, (3) batch distillation, and (4) thin-film evaporation. Process descriptions and flow diagrams for each of these organic removal processes are presented in Chapter 4.0, Section 4.3.

The cost methodology used for the organic removal process cost analyses is identical to the methodology used for the add-on and suppression control cost analyses. This methodology is described in Appendix H.1. An example of how the methodology was applied to an organic removal process is presented in Section I.2.

I.1.2 Hazardous Waste Incinerators

Rotary kiln incinerators can be used to lower the organic content of organic slurry, sludge, or solid hazardous wastes. The minimum destruction efficiency required by the Resource Conservation and Recovery Act (RCRA) regulations for hazardous waste incineration (40 CFR 264, Subpart 0) is 99.99 percent. Additional information about rotary kiln incinerators is presented in Chapter 4.0, Section 4.4.

Rotary kiln incinerator costs were estimated using EPA cost factors. These cost factors were developed to investigate the costs of alternative treatment technologies, including incineration, for disposing of hazardous wastes subject to proposed land disposal restrictions.^{2,3} The cost factors are applicable to rotary kiln incinerators ranging in size from 1.5 to 44 MW.

I.1.3 <u>Waste</u> Stream Composition and Throughput Selection

Many different types of hazardous waste (e.g., liquids, sludges, and solids with different chemical compositions) are processed in TSDF units. Furthermore, the quantity of hazardous waste processed (termed "throughput") at each facility varies significantly. Therefore, it is not reasonable to perform control cost analyses for every possible hazardous waste stream composition and throughput. Instead, the cost analyses were performed for selected hazardous waste stream compositions and throughputs that are representative of existing TSDF operations.

The approach used for selecting the waste compositions and throughputs was to develop model parameters that are typical of existing TSDF hazardous waste stream compositions and process throughputs. The same model parameters are used for: (1) estimating TSDF air emissions, and (2) sizing and costing potential TSDF controls.

The model waste stream compositions used for the cost analyses are described in Appendix C, Table C-5. Because of physical form or chemical composition limitations, not all types of hazardous waste can be treated in all types of organic removal processes. Air and steam strippers typically process dilute aqueous waste, whereas thin-film evaporators process sludges and batch distillation units process organic liquids. Therefore, each organic removal process cost analysis was performed using the model waste stream composition defined for the waste form that is most appropriate for the process. To account for the capability of rotary kiln incinerators to burn a variety of waste forms, cost analyses for the rotary kiln incinerators were performed for the organic sludge/slurry and organiccontaining solid model waste stream compositions.

A specific model process throughput was matched individually to each type of organic removal process and incinerator based on data for typical commercial TSDF operations. Explanations of the selection rationale for each organic removal process and incinerator are presented in References 1, 4, 5, and 6. In general, model process throughputs were selected to be within the range of throughput capacities reported for commercial-scale process units currently in operation.

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I.2 STEAM STRIPPER COST ANALYSIS

This section presents the cost analysis of steam stripper to show the application of the cost analysis methodology to an organic removal process. Similar analyses were performed for air stripping, batch distillation, and thin-film evaporation. The cost analyses calculations and results tables for these processes as well as rotary kiln incinerators are presented in Reference 1.

The basic operating principle of steam stripping is the direct contact of steam with a waste, which results in the transfer of heat to the waste and the vaporization of the volatile constituents. The resulting vapor is condensed and the organics separated from the water and recycled or incinerated. More information about steam stripping is presented in Chapter 4.0, Section 4.3.1.

I.2.1 Process Design Specifications

The first step in the cost analysis was to select values for the key steam stripper design specifications: (1) waste stream composition, (2) process throughput, and (3) organic removal efficiency. These design specifications define the steam stripping unit performance conditions for which the major equipment component sizes (e.g., stripping column, feed preheater, condenser, storage tanks) and utility consumptions (e.g., steam, water, electricity) are calculated. The calculated design values were then used to estimate capital investment and annual costs for a steam stripping unit.

Steam stripping is a commercially proven process that typically is used to remove organics from aqueous waste such as chemical manufacturing and refinery process wastewater. To represent this type of waste for the steam stripper cost analysis, the model waste stream composition was defined as 99.6 percent water and a mixture of six organic compounds. Two compounds were selected to serve as representative organics for each of three volatility classes that were based on ranges of Henry's law constants. The compounds chosen were:

- High volatility: methylene chloride and vinyl chloride
- Medium volatility: pyridine and acrylonitrile
- Low volatility: phenol and o-cresol.

Operating data for four existing commercial-scale steam stripping units were reviewed to select the model waste stream process throughput. The actual process throughputs ranged from 0.02 to 0.85 m³/min (5 to 225 gal/min). Based on this range of actual commercial steam stripping unit throughputs and a cost sensitivity analysis, a model process throughput of 0.28 m³/min (75 gal/min) was selected for the steam stripping cost analysis. This throughput value was judged to be a size that would be practical for onsite waste treatment by waste generators yet that would be of sufficient size to provide the cost-effectiveness advantage of economy of scale.

Selection of organic removal efficiency for the steam stripping cost analysis was based on a review of the field test data compiled for existing commercial-scale steam stripping units (refer to Appendix F, Section F.2.3.1). These data indicate that organic removal efficiencies greater than 90 percent have been achieved by steam stripping units in commercial operation for both high and medium volatility class organic compounds. Therefore, the steam stripper performance level chosen for the cost analysis was 90 percent removal of the organic compound in the medium volatility class that was most difficult to remove. For the model waste stream composition used for the steam stripper cost analysis, this compound is pyridine.

I.2.2 Equipment Component Size Determination

The major steam stripper equipment component sizes were determined using a computer chemical process simulation model called ASPEN (<u>A</u>dvanced <u>System</u> for Process ENgineering).⁷

The ASPEN model was developed by the U.S. Department of Energy and is widely used by industry and universities to design, cost, and optimize chemical process units. Several features of the ASPEN model make it suitable for sizing an organic removal process and its ancillary equipment such as condensers. These are:

- Built-in modular process flowsheets
- Representation of solid materials

- Built-in thermodynamic calculations
- Optimal design capability.

A countercurrent flow steam stripping tower configuration as shown in Figure I-1 was used for the ASPEN simulation. For the cost analysis, it is assumed that the overhead process stream is passed through a two-stage condenser consisting of a water-cooled primary stage and brine-cooled secondary stage. The test data compiled for existing commercial-scale steam stripping units suggest that the highest volatile organic removal efficiencies will be achieved when this type of overhead control is used.

A residual amount of organics remains in stripper bottoms. At existing steam stripping operations, the bottoms process stream normally is discharged to a sewer for treatment at a publicly owned treatment works (POTW) facility. For the ASPEN simulation of a steam stripping process, the residual stream was assumed to be treated in the same manner as the entire waste stream prior to application of the stripper.

Liquid-phase mass transfer coefficients needed to size the steam stripper tower height for a specific removal efficiency were based on the Onda mass transfer model.⁸ Phase equilibrium calculations in the overhead condenser were based on the Soave modification of the Redlich-Kwong equation of state. This equation allows prediction of three-phase equilibrium compositions (i.e., vapor-liquid-liquid compositions).

Using the selected waste composition, process throughput, organic removal efficiency, and design configuration, the ASPEN computer model simulated the steam stripper operation by computing the theoretical material balance, energy balance, and equipment sizes for the desired level of performance. The mass flow rates of the six organic compounds were calculated for each step of the steam stripping process. Table I-1 presents the results of the ASPEN material balance calculations corresponding to the process streams shown in Figure I-1. An energy balance was also computed to determine the amount of steam and electricity needed to achieve the desired performance.

I.2.3 <u>Total Process Cost Estimates</u>

Each steam stripper equipment component size calculated using the ASPEN model was multiplied by an appropriate cost factor to estimate the purchase cost of the required equipment component. These cost factors were



Figure I-1. Schematic of steam stripping process.

Process	Process flow rate, ^c kg/min									
stream number ^b	Vinyl chloride	Methylene chloride	Acrylo- nitrile	Pyridine	o-Cresol	Phenol	Water			
1	Ø.2	0.2	Ø.2	Ø.2	0.2	Ø.2	278			
2	0.002	0.002	0.002	0.002	Ø.ØØ2	0.002	3			
3	Ø.19	Ø.19	Ø.19	Ø.19	Ø.19	Ø.19	275			
4	0.19	Ø.19	Ø.19	Ø.19	Ø.19	Ø.19	275			
5	0.0000	0.0000	0.0002	Ø.Ø19	Ø.13	Ø.18	275			
6	Ø	ø	ø	ø	Ø	Ø	36			
7	Ø.19	Ø.19	Ø.19	0.17	0.06	0.014	36			
8	Ø.19	Ø.16	Ø.19	Ø.Ø9	Ø.ØØ5	0.0001	ø			
9	0.004	0.04	0,003	0.08	Ø.055	0.014	36			
1Ø	0.006	0.001	0.0001	0.0000	0.0000	0.0000	ø			
11	Ø.18	Ø.16	Ø.19	Ø.Ø9	Ø.Ø05	0.0001	ø			

TABLE I-1. MATERIAL BALANCE FOR A STEAM STRIPPING ORGANIC REMOVAL PROCESS^a

^aThis table presents the material balance calculated by the ASPEN chemical process simulation model for the steam stripping of a dilute aqueous waste containing the following compounds and concentrations:

Vinyl chloride	. Ø, Ø7%
Methylene chloride	0.07%
Pyridine	Ø.Ø7%
Phenol	Ø.Ø7%
Acrylonitrile	0.07%
o - Cresol	Ø.Ø7%
Water	99.6%

The stripper is designed to remove 90 percent of the pyridine at a process throughput of $0.28 \text{ m}^3/\text{min}$ (75 gal/min).

bStream numbers refer to the schematic diagram presented in Figure I-1.

CFlow rates calculated by ASPEN and manually rounded for presentation in this table.

obtained from published cost correlations commonly used to estimate chemical process costs. The references for these equipment component cost factors are listed in Table I-2. Table I-2 presents the base equipment cost (BEC) for the steam stripper. This cost is the sum of the major equipment component costs such as the stripping column, decanters, feed preheater, and condensers.

Total capital investment is presented in Table I-3. The installation costs, both direct and indirect, are calculated by a percentage of the purchased equipment cost (PEC). The percent values used for the installation cost estimates are listed in Table I-3. Further explanation of the costing factors is provided in Reference 1 and Appendix H.

The total annual cost is presented in Table I-4. This cost is the sum of the direct annual costs (e.g., utilities, labor, and maintenance), the indirect annual costs (e.g., overhead, property taxes, insurance, administrative charges, and capital recovery), and any recovery credits. An explanation of the basis for recovery credits is given in Appendix H, Section H.1.3. The annual operating cost is defined as the total annual cost minus capital recovery. For a total waste throughput of 122,000 Mg/yr, the steam stripping system has an estimated cost of approximately \$4.50/Mg of throughput.

I.2.4 Modular Cost Estimates

To determine the cost effectiveness (cost per unit throughput) of the major steam stripping components, the process was divided into four modules. The modules are shown in Figure I-1 and identified as: (1) storage and handling, (2) organic removal, (3) overhead control, and (4) bottoms handling. The capital investment and annual costs for organic removal were estimated for each module. The following guidelines were followed in assigning costs to each module:

- Direct and indirect installation cost factors are the same for all modules in the steam stripping process and are equal to the factors used for the whole process.
- Labor costs are proportioned among the steam stripping modules as follows: 85 percent to organic removal, 5 percent each to storage/handling, overhead control, and bottoms handling.

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Equipment component	Component sized	Number of components	Materials of construction	Purchase cost, ^b \$	Cost factor source ^c
Storage tanks	204 m ³	2	Carbon steel	66,000	9
Stripping column	Ø.76 m d ia . x 42 m high	1	Carbon steel	90,000	10
Decanter	95 m ³	2	Carbon steel	50,000	9
Feed preheater	978 m ²	1	Carbon steel	116,000	7
Primary condenser	56 m ²	1	Carbon steel	13,000	7
Secondary condenser	14 m ²	1	Carbon steel	7,000	7
Refrigeration unit	35Ø W	1	NA	7,000	9
Flame arrestors	NA	4	NA	1,000	11
Total base equipment cost (BEC)				\$350,000	

TABLE I-	2. BASE	EQUIPMENT	COSTS	FOR A	STEAM	STRIPPING	ORGANIC	REMOVAL	PROCESSa
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- - -----

NA = Not applicable.

^aThis table presents estimates of the major equipment purchase costs required for the steam stripping of a dilute aqueous waste.

^bAll costs rounded to the nearest \$1,000 and expressed in January 1986 dollars.

^CNumber refers to reference listed in Section I.4.

^dEquipment component sizes were calculated by ASPEN computer simulation using the model waste composition shown in Table I-1 and a process throughput of Ø.28 m³/min (75 gal/min).

TABLE I-3.	TOTAL CAPITAL	INVESTMENT	FOR A	STEAM	STRIPPING
	ORGANIC F	REMOVAL PROG	CESSa		

Cost item	Value	Cost ^b \$	Cost factor source ^c
Direct equipment costs			
Base equipment cost (BEC) Pumps (#)		350,000 Ød	Table I-2
Ductwork	244 m at \$11.98/m	3.000	12
Instrumentation	10% (BEC + pumps + ductwork)	35,000	13 14
Sales taxes & freight	8% (BEC + pumps + instr. + ductwork)	31,000	15,16
Purchased equipment cost (PEC)	· · · · · · · · · · · · · · · · · · ·	419,000	
Direct installation costs			15,16
Support	7% of PEC	30,000	
Electrical	4% of PEC	17,000	
Erection	20% of PEC	84,000	
Painting	1% of PEC	4,000	
Site preparation	1% of PEC	4,000	
Indirect installation costs			15,16
Engineering	10% of PEC	42,000	
Construction & field expenses	7% of PEC	30,000	
Construction fee	10% of PEC	42,000	
Startup and testing	2% of PEC	8,000	
Contingency	5% of PEC	21,000	17

Total capital investment (TCI)

\$701,000

^aThis table presents estimates of direct and indirect capital costs for the steam stripping of a dilute aqueous waste. Installation costs and equipment costs are added to estimate the total capital investment.

^bAll costs rounded to nearest 1,000 and expressed in January 1986 dollars.

^CNumber refers to reference listed in Section I.4.

 d_{Pumps} are implicitly included in the assignment of direct installation factors.

Cost item	Value or unit price, units	Annual consumption, units	Annual cost, ^b \$	Cost factor source ^c
Direct annual costs				
Utilities ^d Electricity Steam Water	\$0.0463/kWh \$3.09/10 ⁹ J \$0.04/m ³	3 × 10 ⁶ kWh 3.5 × 10 ¹³ J 4.8 × 10 ⁵ m ³	140,000 107,500 19,000	18 18 18
Labor Operating labor Supervision & administration	\$12/h 15% of direct labor	7,200 h ^d NA	86,500 13,000	16 16
Maintenance Labor Materials	\$13.20/h 100% of maint. labor	795 h NA	10,500 10,500	19 2Ø
Total direct annual costs			\$ 387,000	
Indirect annual costs				
Overhead Property taxes Insurance Administrative charges Capital recovery	60% of (total labor costs) 2% of TCI 1% of TCI 1% of TCI 1% of TCI 10% at 15 yr		72,000 14,000 7,000 7,000 92,000	21 15,16 15,16 15,16 15,16
Total indirect annual costs			\$ 192, Ø ØØ	15,16
Recovery credits ^e			\$27,000	
Total annual cost ^f	Direct + indirect costs - recovery credits		\$ 552,000	
See notes at end of table.			(c	ontinued)

TABLE I-4. TOTAL ANNUAL COST FOR A STEAM STRIPPING ORGANIC REMOVAL PROCESS

Cost item	Value or unit price, units	Annual consumption, units	Annua! cost, ^b \$	Cost factor source ^c
Annual operating cost9	TAC-capital recovery		460,000	
Throughput	Mg/yr		122,000	
Cost/throughput ^h	\$/Mg		4.53	

TABLE I-4. (concluded)

NA = Not applicable.

TCI = Total capital investment.

^aThis table presents estimates of direct and indirect annual operating costs for the steam stripping of a dilute aqueous waste. Annual operating costs are added to capital recovery costs to estimate total annual costs. Total annual cost is divided by the annual process throughput to estimate the cost effectiveness of using steam stripping to remove organics from a dilute aqueous stream.

^bAll costs rounded to nearest \$1,000 and expressed in January 1986 dollars.

^CNumber refers to reference listed in Section I.4.

dUtility consumption was calculated by ASPEN computer simulation model assuming unit is operated 24 h/d, 300 d/yr.

^eRecovery of condensed organics produces a liquid that can be used as a fuel in boilers and other combustion devices. For this cost analysis, no cost credit was taken for the recovered organics.

^fSum of total direct annual cost plus total indirect annual cost.

9Total annual cost minus capital recovery.

^hTotal annual cost divided by throughput.

• Utilities (electricity, steam, water) consumption is assigned to each module according to the material and energy balance.

Table I-5 presents the capital investment and operating costs for the four modules. The total annual cost shown in Table I-5 includes capital recovery (10 percent interest over a service life of 15 yr) as an indirect annual cost. Any credits for recovery of condensed organics are also included in the total annual cost.

I.3 SUMMARY OF ORGANIC REMOVAL PROCESS AND INCINERATOR CONTROL COSTS

Organic removal process and incinerator control costs are summarized in Table I-6. This table shows the total capital investment, annual operating cost, and total annual cost for each process evaluated. Also presented are the total annual cost per megagram of throughput and per megagram of organic removed. The complete cost analysis results for all of the processes are presented in Reference 1.

Total capital investment for an organic removal process ranges from about \$328,000 for a batch distillation unit to \$1.5 million for a thinfilm evaporator. Total capital cost for a rotary kiln incinerator ranges from approximately \$13 million for firing organic sludge/slurry to approximately \$21 million for firing an organic-containing solid.

Annual operating cost for an organic removal process ranges from a credit of \$391,000 for the batch distillation unit to a cost of \$463,000 for the steam stripper. The credit for batch distillation results from the recovery of organic compounds for use as a waste fuel. The value of the recovery credit was estimated based on the heat content of the recovered organics. Annual operating cost for a rotary kiln incinerator ranges from approximately \$1.9 million for firing an organic sludge/slurry to \$4.7 million for firing an organic-containing solid.

The cost per megagram of waste throughput for an organic removal process ranges from a credit of \$23/Mg for a batch distillation unit handling an organic liquid to \$33/Mg for a thin-film evaporator handling an aqueous sludge/slurry. The cost per megagram of throughput for a rotary kiln incinerator ranges from \$110/Mg for firing an organic-containing solid to \$146/Mg for firing an organic sludge/slurry.

Steam stripping unit module	Total capital investment	Annual operating costb	Total annual cost ^C				
Storage & handling	\$134,000	\$22,000	\$39,000				
Organic removal	\$565,000	\$405,000	\$479,000				
Overhead control	\$2,000	\$17,000	\$17,000				
Bottoms controld	\$0	\$17,000	\$17,000				
Total	\$701,000	\$461,000	\$552,000				

TABLE I-5. COMPARISON OF MODULAR COSTS FOR A STEAM STRIPPING ORGANIC REMOVAL PROCESS^a

^aThis table compares the cost estimates for the steam stripping unit modules shown in Figure I-1, i.e., storage and handling, organic removal, overhead control, and bottoms handling. Costs are presented in January 1986 dollars. Capital costs for storage apply only at TSDF that do not have existing tank or drum storage.

^DAnnual operating cost, excludes capital recovery. Recovery credit is taken in the organic removal module.

^CTotal annual cost, includes capital recovery.

^dThe cost of bottoms handling is estimated by attributing a portion of the operating labor, utilities, and indirect annual costs to the handling of the steam stripper bottoms.

Control	Organic removal efficiency, ^Ł X	í	Model waste stream ^c	Model unit throughput, ^d Mg/yr	Total capital, investment, ^e \$	Annual oper. cost, ^e \$	Tota¦ annual cost, ^e \$	\$/Mg throughput	\$/Mg organic removed
Rotary-kiln incinerator	99.99		Organic sludge/slurry	26,900	12,900,000	1,920,000	4,020,000	146	146
Rotary-kiln incinerator	99.99		Organic-containing solid	74,000	21,300,000	4,740,000	8,210,000	110	11,000 ⁱ
Air stripping ^f	High volatile Medium volatile Low volatile	99.0 13.7 1.1	Dilute aqueous-3	81,600	818,000	80,600	188,000	2.3	15,200 ⁱ
Steam stripping9	High Volatile Medium volatile Low volatile	99.99 99.96 16.5	Dilute aqueous-2	122,000	701,000	461,000	552,000	4.53	1,600 ¹
Batch distillation ^f	High volatile Medium volatile Low volatile	99.0 18.0 6.0	Organic liquid	17,300	328,000	(391,000)	(348,000)	(22.60)	(48.04)
Thin-film evaporatorh	High volatile Medium volatile Low volatile	99.8 65.9 20.7	Aqueous sludge/slurry	17,600	1,510,000	340,000	586, 000	33.3	536

TABLE I-6.	SUMMARY (0F	ESTIMATED	ORGANIC	REMOVAL	PROCESS	AND	HAZARDOUS	WASTE	INCINERATOR	CONTROL	COSTS

Mg = Møgagram.

() indicates a cost credit.

^aThis table shows the estimated costs of processing the identified waste stream.

^bOrganic removal efficiency is defined as the fraction of organic material in a waste stream that is removed either by separation or incineration. For hazardous waste incineration, all organic compounds are estimated to be removed at an efficiency of 99,99 percent. For organic removal processes, the control is designed to remove a high or medium volatility compound at a specific efficiency. Lower volatility compounds included in the model waste stream are removed with less efficiency. The overall efficiency of organic removal processes depends on the actual waste stream composition.

CFor initial waste stream compositions, refer to Appendix C, Table C-5.

dWaste stream throughputs are based on data for existing process units.

eAll costs are expressed in January 1986 dollars.

^fCosts based on a process designed to remove 99 percent of the most volatile compound in the model waste stream.

9Costs based on a process designed to remove at least 90 percent of the medium volatility class compounds in the model waste.

hCosts based on a process designed to achieve removal efficiencies demonstrated by test results for a pilot-scale thin-film evaporator unit.

ⁱCosts per megagram of organic removed are high for these control options because of the very low organic content of the waste.

The cost per megagram of organic removed ranges from a credit of \$48 for a batch distillation unit to \$15,200 for an air stripper operating on a dilute aqueous waste. The high cost per unit of organic removed for the steam stripper is due primarily to the very low organic content (0.4 percent) in the dilute aqueous waste stream. For a rotary kiln incinerator, the cost per megagram of organic removed ranges from a credit of \$146/Mg for firing an organic sludge/slurry to \$11,000/Mg for firing an organic-containing solid. The high cost of organic destruction for the rotary kiln incinerator firing organic-containing solids is due to the small concentration of organics in the organic-containing solid (1 percent aceto-nitrile).

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APPENDIX J

EXPOSURE ASSESSMENT FOR MAXIMUM RISK AND NONCANCER HEALTH EFFECTS

APPENDIX J

EXPOSURE ASSESSMENT FOR MAXIMUM RISK AND NONCANCER HEALTH EFFECTS

The purpose of this appendix is to present the treatment, storage, and disposal facility (TSDF) data and the models used to assess chronic and acute risk from TSDF air emissions. Chronic risk is expressed as (1) risk of contracting cancer from long-term (e.g., 70 years) exposure to carcinogenic agents, and (2) risk of adverse health effects from long-term exposure to noncarcinogenic agents. Acute risk is expressed as the risk of adverse noncancer health effects from exposure to short-term, concentrated TSDF emissions of chemical agents.

Chronic risk is assessed using the maximum annual average ambient concentrations estimated from (1) the emission models, and (2) the Industrial Source Complex Long-term (ISCLT) model. Acute risk is assessed from the short-term (peak) ambient concentrations estimated from (1) the short-term emission models and (2) the Industrial Source Complex Short-term (ISCST) model. Each ISC model calculates the ambient concentration of the waste constituents or their surrogates in TSDF emissions dispersed at the facility fenceline and beyond. To calculate chronic cancer risk, the ambient concentration is multiplied by a constituent's or surrogate's unit risk factor (see Appendix E). Chronic and acute noncancer health effects are assessed by comparing the ambient concentration of constituents to their reference doses (RFDs) (see Appendix E). The modeling is performed not only to assess risk from exposure to uncontrolled TSDF emissions but also to evaluate the effectiveness of control techniques in lowering TSDF emissions and risk. Appendix E provides a detailed discussion of these risk assessment procedures.

Briefly, the steps required to assess risk are as follows:

- Characterize the TSDF of interest.
- Collect meteorological data (hourly for short-term assessments and annual frequency distribution for long-term assessments).
- Identify the characteristics of wastes managed at the TSDF.
- Generate organic emission rates (hourly for short-term assessments and annual average for long-term assessments).
- Execute dispersion modeling of the organic emissions.
- Identify the highest ambient concentration of the organic emissions.

Chapter 6.0 presents the results of the ISCLT for chronic cancer risk as maximum lifetime risk. Chronic and acute risk assessments for noncarcinogenic TSDF emissions are still in progress.

This appendix discusses the models used to estimate short-term and annual average concentrations used in the health effects assessment. It presents the TSDF characterized for the risk assessment and then addresses the information used to assess the reduction in risk once emission controls are in place.

To expand on these particular model inputs, data generated and their corresponding Appendix J sections include:

- TSDF long-term emission models (Section J.1.1)
- TSDF short-term emission models (Section J.1.2)
- TSDF to be modeled including their plot plans, design and operating parameters, and waste characterization (Section J.2)
- Long-term example control strategies and emission estimates (Section J.3)
- Short-term control strategies (Section J.4, currently not available)
- Dispersion modeling for chronic health effects (Section J.5).

Chronic risk estimates are computed using long-term TSDF emission estimates. The long-term emission models discussed in Section J.1.1 are the same as those summarized in Appendix C, Section C.1. (A detailed description of emission models is contained in a recent TSDF air emissions models report.¹) The emission models compute the emission of organic surrogates (defined in Appendix D, Section D.2.3) for chronic cancer effects. Physical properties of each surrogate are classified according to (1) Henry's law constant and biodegradability, or (2) vapor pressure and biodegradability. Table J-1 lists the physical properties of surrogates (numbered 1 through 9) associated with values of Henry's law constant and the physical properties of surrogates (numbered 1 through 12) used with values of vapor pressure. (The properties associated with the Henry's law constants are valid for dilute aqueous wastes; the properties for vapor pressure are used for oily or more concentrated organic wastes.)

Chronic noncancer effects will be evaluated using specific chemicals instead of organic surrogates. Waste constituents of interest will be modeled using the long-term emission models and the ISCLT model to estimate annual ambient concentrations. These concentrations will be compared to health benchmark values for each constituent to assess chronic noncancer effects of ISDF air emissions.

Acute risk assessments must be based on short-term TSDF emission estimates; therefore, it was necessary to modify the long-term emission models in Appendix C to estimate emissions on an hourly basis. These modifications (summarized in Section J.1.2) are explained in Reference 2. The emission models compute the emission of specific waste constituents from the two modeled TSDF. Physical properties of each waste constituent are taken from an appropriate surrogate listed in Table J-1.

In Section J.2, the selection of facilities to be modeled is addressed. As explained in Chapter 6.0, the detailed and accurate data necessary to estimate risk for each TSDF in the Nation and, in turn, identify the TSDF causing the maximum risk in the Nation were not available. Therefore, two TSDF were selected to estimate chronic cancer risk (referred to as maximum lifetime risk), and chronic and acute noncancer health effects. The following topics are discussed for the two TSDF selected:

- Comparison of TSDF selected to characteristics of TSDF nationwide
- Description of each TSDF

Surrog	ates ^c	Molecular weight, g/g mol	Diff. water, (10 ⁻⁶ cm ² /s)	Physical propert Diff. air, (10 ⁻² cm ² /s)	ies associated w Biorate, mg organics/ g/h	ith Henry's law ^b Henry's law constant, atm·m ³ /g mol (T = Kelvin)	Henry's law constant at 298 K (10 ⁻⁶ atm·m ³ /g mol)
MHLB HHLB LHMB	6 3 8,9	112 144 78.4	8.60 9.39 11.3	7.64 8.76 18.0	Ø.390 Ø.302 3.55	$H = (e ((-4,879.12/T)+17.1726))/10^{5}$ $H = (e ((-2,275.38/T)+15.6418))/10^{5}$ H = e ((-11,562.27/T)+23.14) H = e ((-11,562.27/T)+23.14)	22.2 30,000 0.158 40.8
мнмв ННМВ LHHB MHHB НННВ	5 2 7 4 1	67.0 117 97.3 69.9 98.4	11.8 8.24 9.64 11.6 9.4	11.5 7.40 8.27 9.56 8.73	11.2 2.71 23.2 40.1 29.2	$ \begin{array}{l} H = (e \ ((-4,090.1b/1)+1b.13143))/10^5 \\ H = (e \ ((-5,462.87/T)+23.10247))/10^5 \\ H = e \ ((-11,562.27/T)+23.14) \\ H = (e \ ((-3,256.36/T)+12.84471))/10^5 \\ H = (e \ ((-3,180.14/T)+16.95871))/10^5 \end{array} $	40.8 1,180 0.158 68.0 5,380

TABLE J-1. PHYSICAL PROPERTIES OF ORGANIC SURROGATES USED IN THE DETAILED FACILITY ANALYSES^a

Physical properties associated with vapor pressured

		Molecular weight,	Diff. water,	Diff. air,	Biorate, mg organics/	Vapor pressure, mm Hg	Vapor pressure	
Surrogates ^c		g/g mol	$(10^{-6} \text{ cm}^2/\text{s})$	$(10^{-2} \text{ cm}^2/\text{s})$	g/h	(T = Celsius)	at 25 °C	
нунв	1	74.4	10.6	9.89	34.30	VP = 10 [0.0187T + 1.846]	206	
HVMB	2	72.5	10.7	13.4	Б.97	VP = 10 [0.01685T + 1.8388]	182	
HVLB	3	117.Ø	9.63	8.99	0.30	VP = 10 [0.014475T + 2.046]	256	
MVHB	4	111.0	9.02	7.68	22.60	VP = 10 [0.0335T - 0.4192]	2.62	
₩VMB	5	132.0	7.50	6.43	3.02	VP = 10 [0.02415T - 0.2984]	2.02	
MVLB	6	185.Ø	7.32	6.69	Ø.39	VP = 10 [0.0256T - 0.176]	2.91	
LVMB	7,8,9	98.Ø	11.1	9.50	4.08	VP = 10 [0.07716T - 5.929]	0.0001	
VHVHB	10,11	39.3	14.6	10.1	47.5Ø	VP = 10 [0.0138T + 2.9315]	1,890	
VHVLB	12	80.7	11.8	10.7	Ø.3Ø	VP = 10 [0.0135T + 2.97]	2,030	

^aSurrogate properties (defined in Appendix D, Section D.2.3.3) are classified into two groups: physical properties associated with Henry's law, and physical properties associated with vapor pressure.

^bLow Henry's law constant less than 1.0 x 10^{-5} atm m³/g mol. Medium Henry's law constant 1.0 x 10^{-5} to 1.0 x 10^{-3} atm m³/g mol. High Henry's law constant greater than 1.0 x 10^{-3} atm m³/g mol.

^CSurrogate codes:

MHLB = Medium Henry's law, low biodegradation. HHLB = High Henry's law, low biodegradation. LHMB = Low Henry's law, medium biodgradation. MHMB = Medium Henry's law, medium biodegradation. HHMB = High Henry's law, medium biodegradation. LHHB = Low Henry's law, high biodegradation. MHHB = Medium Henry's law, high biodegradation. HHHB = High Henry's law, high biodegradation. HVHB = High volatility, high biodegradation HVMB = High volatility, medium biodegradation. HVLB = High volatility, low biodegradation. MVHB = Medium volatility, high biodegradation. MVMB = Medium volatility, medium biodegradation. MVLB = Medium volatility, low biodegradation. LVMB = Low volatility, medium biodegradation. VHVHB = Very high volatility, high biodegradation. VHVLB = Very high volatility, low biodegradation. dLow volatility less than 0.0076 mm Hg.

Medium volatility 0.0076 to 0.76 mm Hg. High volatility 0.76 to 760 mm Hg.

Very high volatility greater than 760 mm Hg.

- Source of data
- Plant layout
- Waste managed and their characteristics.

The plot plans and design and operating parameters of each facility also are presented.

For long-term emission control, the two example control strategies described in Chapter 5.0 are applied in Section J.3. Efforts to identify controls for both acute and chronic noncarcinogenic TSDF emissions are still in progress. No information is currently available on short-term controls for Section J.4.

J.1 TSDF EMISSION MODELS

Estimates of air emissions from the two TSDF described in this appendix include both short-term or peak emissions and annual average emissions. The emission models derived for short-term estimates use inputs that are based primarily on a high level of activity with most transfers of waste occurring during an 8-h period each day. The approach for average annual emissions assumes a relatively continuous operation, and the emission models for annual average estimates use inputs based on average flow rates, a temperature commonly used in emission modeling, and an average annual windspeed.

J.1.1 Long-Term Emission Models

Annual average or long-term emissions are estimated from the emission models presented in the TSDF air emission models report. This approach is based on annual average waste flow rates (instead of the peak rates used for the short-term approach) and average meteorological conditions. The source descriptions and dimensions used as inputs to the models are the same as those used for the short-term effort and are described in Section J.2.

For both sites, a temperature of 25 °C was used as recommended in Reference 1. The frequency of occurrence of various windspeeds at each site was used to estimate an annual average windspeed. The average annual windspeed used for TSDF Site 1 was 3.5 m/s and the windspeed used for Site 2 was 4.5 m/s. None of the TSDF emission sources were defined as biologically active treatment systems; consequently, biodegradation was not

included in the emission models. The annual average estimates for each source include adjustments to the organic concentration in the waste to reflect losses due to air emissions from prior processing.

J.1.2 Short-Term Emission Models

The models used to estimate short-term emissions are discussed in detail in Reference 2 and are based on modifications to the annual average models presented in the TSDF air emission models report. A basic modification used for the short-term models is to present the input parameters and mass transfer correlations in terms of their dependence on temperature and windspeed. Accounting for short-term variations in temperature and windspeed will then yield more accurate estimates of short-term emissions. For example, the following properties were expressed in terms of their temperature dependence: vapor pressure, Henry's law constant, diffusivity of a compound in air and water, density and viscosity of air, and diffusion coefficients. For models that contain windspeed as an input parameter, the functional dependence on windspeed was retained as a variable.

The short-term approach uses site-specific data on temperature and windspeed to estimate emissions for short time intervals. The temperature and windspeed are updated hourly to estimate hourly instantaneous emissions from each source. The emission estimates generated in this manner permit peak emission periods to be identified and also allows the estimation of peak ambient air concentrations of organics around the facility. This approach also reduces the organic concentration as the waste is processed to reflect losses to the air from previous process emission sources. The emission source descriptions, including method of operation, peak waste pumping rates and pumping times, and process unit dimensions used in the short-term models are provided in Section J.2.

J.2 TREATMENT, STORAGE, AND DISPOSAL FACILITIES SELECTED FOR DETAILED ANALYSIS

This section introduces two TSDF selected for modeling the dispersion of organic emissions to assess chronic and acute health effects from exposure to ambient air concentrations. These TSDF are based on actual facilities.

In Sections J.2.2 and J.2.3, each TSDF emission source is described, including quantity of waste transferred, loading times, dimensions of emission source, and input parameters for the appropriate emission calculations.

The data used to characterize both facilities came from test reports prepared for EPA, along with the Industry Profile and the Waste Characterization Data Base (WCDB). (The Industry Profile and WCDB are described in more detail in Appendix D.) This information was supplemented by discussions with EPA Regions, State agencies, RCRA permit applications, and the 1986 National Screening Survey.³

Representative waste concentrations were developed for chemical constituents and their organic surrogates for Sites 1 and 2 as an input to the emission models. Using the Industry Profile along with the test reports prepared for EPA, waste stream mixtures consisting of RCRA waste codes, their physical/chemical forms, and quantities were designated for each waste management process (multiple waste codes may be mixed and managed in the same process). All of the waste data bases constituting the WCDB (see Appendix D, Section D.2.2) were then accessed to provide compositional data for determining representative waste concentrations of constituents or surrogates. Default compositions (described in Appendix D, Section D.2.2) were used to characterize waste streams that were undefined in the WCDB. The methodology for developing constituent and surrogate concentrations is documented in Reference 4.

J.2.1 <u>Rationale for Selection of Facilities</u>

As noted earlier, two TSDF were selected for modeling in order to assess chronic and acute health effects from exposure to air emissions at the facilities. For these assessments, the highest ambient concentrations in the vicinity of the facilities are used to assess the potential for the greatest human exposure. The highest ambient concentrations around a facility are sensitive to a number of factors, including:

- Magnitude and rate of emissions from all sources of air emissions at a facility
- Emission release characteristics such as temperature, height of release, the area over which the emissions occur, etc.

- Location of the emission sources relative to the impact area
- Meteorology at the site that affects both emission rates (e.g., temperature and windspeed) and transport and dispersion of the emissions (e.g., windspeed, wind direction, atmospheric stability, depth of the mixed layer, etc.).

Ideally, the facilities selected for analysis would be those that are indicative of the highest exposures around TSDF. Because of the complex nature of TSDF and the dependency of ambient concentration estimates on the factors cited above, selecting facilities that have the greatest potential for the highest ambient concentrations is extremely difficult. Thus, the approach used here was to select the facilities on the basis of a number of criteria, including:

- Sufficient information on the facility must be available in order to properly characterize it for emission model and refined dispersion model applications
- The facilities should contain a variety of TSDF emission sources in order to evaluate the effectiveness of alternative control strategies on lowering emissions from the various source types
- The facilities should have significant waste volume throughputs to maximize the potential for high emissions.

Inital screening of all TSDF identified relatively few sites with the necessary information to perform a refined modeling analysis and meet the above criteria. Of these, two sites that best met the criteria were selected after reviewing the available information on emission source types, forms of waste handled, site layout, and process flow. J.2.2 Description of Site 1

Site 1 is a commercial hazardous waste management facility. The facility accepts a variety of hazardous wastes, both in bulk and in containers. Much of the waste that the facility handles is treated onsite, and it consists primarily of wastewater containing soluble oils, acids, caustics, chromium, cyanides, and some solvents. Waste entering Site 1 arrives in drums and by tank truck. The facility has wastewater and waste oil treatment units. Figure J-1 presents a plot plan of Site 1 and Figure J-2 presents a flow diagram of Site 1. The plot plan shows numbered emission sources that correspond to the same description of the facility. The flow diagram contains alphabetized process flows that are keyed to short-term and continuous (annual average) flow rates in Table J-2.

The contents (waste form and code) of each waste mixture managed at Site 1 are presented in Table J-3. The average concentrations of waste constituents of a health concern in each waste stream mixture managed in a process unit on Site 1 are shown in Table J-4; average waste compositions of each waste mixture expressed as organic surrogates are listed in Table J-5. Design and operating parameters for the site along with the appropriate emission calculations are described in the following section.

J.2.2.1 <u>Design and Operating Parameters of Emission Points for</u> <u>Site 1</u>. The following pages present the design and operating parameters of Site 1 emission sources. Each numbered emission source is identified in the plot plan, as shown in Figure J-1. For each emission point within a source, the reader is referred to the modified TSDF emission equations of Reference 2 when dealing with short-term emission estimates. Table J-6 presents the definitions of variables listed for each emission source when estimating short-term emissions.

J.2.2.1.1 <u>Storage and transfer building (emission source No. 1)</u>. Five hundred 0.21-m³ (55-gal) drums arrive each week. Drums are sampled and moved to separate hazard class storage areas. The contents of 250 of these drums are stored in three covered $23-m^3$ aqueous waste storage tanks (3 m x 3 m x 2.5 m). It is assumed that each drum contains 15 percent solids. Solids are consolidated into drums and shipped offsite for disposal.

Each week, two $23-m^3$ tank trucks transfer the aqueous waste from the drum storage building to the acid/alkali receiving area. Tank truck loading occurs on Monday and Thursday at 1000 hours for 1 h at a rate of 6.72 x 10^{-3} m³/s.

Pumping and Piping Refer to Table 3 in Reference 2. Assume all surrogates are heavy liquids.






Figure J-2. Detailed facility analysis: treatment, storage, and disposal facility, Site 1 flow diagram.

Process flow path ^b	Short-term flow rates, ^c 10 ⁻³ m ³ /s	Short-term timeframe	Continuous flow rates,d 10-3 m3/s
A. B. C. D. E. F. G. H. I. J. K. L. M. N. O. P. Q. R. S. T. U. V.	$\begin{array}{c} 0.258\\ 0.018\\ 6.72\\ 6.5\\ 8.42\\ 28.9\\ 0.516\\ 0.611\\ 6.23\\ 3.72\\ 2.5\\ 0.343\\ 0.343\\ 2.16\\ 1.89\\ 2.03\\ 0.00845\\ 1.89\\ 0.132\\ 0.744\\ 0.0929\\ 6.3 \end{array}$	<pre>(7 d/wk, 8 h/d) (7 d/wk, 8 h/d) (2 h/wk) (7 d/wk, 1 h/d) (7 d/wk, 1 h/d) (1 d/wk, 1 h/d) (1 d/wk, 8 h/d) (7 d/wk, 8 h/d) (1 h/mo) (7 d/wk, 8 h/d) (1 d/wk, 2 h/d)</pre>	$\begin{array}{c} 0.086\\ 0.006\\ 0.08\\ 0.27\\ 0.35\\ 0.172\\ 0.172\\ 0.204\\ 2.08\\ 1.24\\ 0.833\\ 0.114\\ 0.833\\ 0.114\\ 0.114\\ 0.72\\ 0.63\\ 0.677\\ 0.00282\\ 0.0028\\ 0.0$

TABLE J-2. DETAILED FACILITY ANALYSIS: SHORT-TERM AND CONTINUOUS PROCESS FLOW RATES WITHIN TSDF SITE 1^a

TSDF = Transfer, storage, and disposal facility.

^aThis table presents short-term and continuous flow rates that are based on site-specific information.

^bHazardous waste management process flow paths are alphabetized to correspond to Figure J-2.

^CShort-term flow rates were estimated based on site-specific information.

^dContinuous flow rates used to estimate long-term emissions were estimated given nonstop flow through the facility 7 d/wk, 24 h/d.

Waste mixture number: ^b	1	2	3	4	Б	6	7	8	9	iø	11	12
Percent comp. by waste form: ^c	25% 2XX 75% 3XX	100% 3XX	100% 4XX	30% 2XX 70% 3XX	24% 3XX 75% 3XX	30% 2XX 70% 3XX	30% 2XX 70% 3XX	30% 2XX 70% 3XX	100% 4XX	100% 4XX	100% 3XX	100% 2XX
RCRA waste code within each waste form:	D004 D005 D009 F006 F007 F008 F009 F011 K052 K086 P021 P029 P074 P098 P121 U134	D004 D005 D009 D010 F006 F007 F008 F009 F011 F012 K052 K086 P021 P029 P074 P029 P074 P098 P121 U134	F001 F002 F003 F004 F005 P005 U001 U002 U012 U019 U028 U031 U037 U052 U070 U071 U076 U077 U076 U077 U076 U077 U076 U077 U076 U071 U076 U077 U076 U071 U076 U077 U076 U112 U122 U122 U122 U122 U122 U122 U12	D004 D005 D009 D010 K052	F001 F002 F003 F004 F005 U001 U002 U012 U019 U028 U031 U037 U052 U070 U071 U076 U077 U080 U112 U121 U121 U121 U122 U165 U188 U191 U208 U209 U210 U226 U227	D004 D005 D009 D010 F006 F019 K052 K086 U134	0004 0005 0009 0010 K052	F007 F008 F011 F012 P029 P074 P098 P121	F001 F002 U037 U070 U071 U076 U077 U080 U121 U208 U209 U210 U226 U227	F003 F004 F005 U001 U002 U012 U012 U012 U028 U031 U037 U052 U112 U122 U140 U154 U159 U161 U165 U188 U191 U213 U220	F003 F004 F005 U001 U002 U012 U012 U012 U028 U031 U037 U052 U112 U122 U140 U154 U159 U161 U165 U188 U191 U213 U220	DØØ4 DØØ5 DØØ9 DØ10 FØ06 FØ07 FØ11 FØ12 KØ86 PØ05 PØ21 PØ29 PØ74 PØ98 P121 U134

TABLE J-3. DETAILED FACILITY ANALYSIS: CONTENTS OF EACH WASTE MIXTURE MANAGED AT TSDF SITE 1ª

- --

TSDF = Treatment, storage, and disposal facility.

RCRA = Resource Conservation and Recovery Act.

2XX = Aqueous sludge.

3XX = Aqueous liquid.

4XX = Organic liquid.

^aThis table presents the RCRA waste codes (and their physical/chemical forms) managed in each waste mixture at Site 1.

^bWaste mixture numbers correspond to the mixture of RCRA waste codes and their forms that enter waste management units at TSDF Site 1. These mixtures are labeled in Figure J-2.

^CA waste mixture may be a combination of two or more physical/chemical waste forms of a RCRA waste code. These forms are described in Appendix D, Section D.2.2.

dRCRA waste codes are defined in 40 CFR 261, Subparts C and D.

Waste mixture	<u>Surro</u> Hi ^b	gate VPi ^C	Average concentration, %	Constituent
1 1 1 1 1 1	1 4 5 3 7 9	1 1 2 3 4 6	0.0001 0.0361 0.0941 0.0001 0.001 0.132	Methylene chloride Ethyl acetate Ethyl alcohol 1,1,1-Trichloroethane Phenols Cyanide
		Tot	al organic = 0.81	8
2 2 2 2	4 5 7 9	1 2 4 6	0.0352 0.0916 0.0001 0.175	Ethyl acetate Ethyl alcohol Phenols Cyanide
		Tot	al organic = 0.62	0
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	$ \begin{array}{c} 1\\1\\4\\4\\4\\7\\5\\5\\5\\3\\3\\3\\6\\6\\1\\1\\1\\7\\7\end{array} $	$ \begin{array}{c} 1\\ 1\\ 1\\ 1\\ 1\\ 1\\ 2\\ 2\\ 3\\ 3\\ 3\\ 3\\ 3\\ 3\\ 3\\ 3\\ 3\\ 3\\ 3\\ 4\\ 4\\ 4\\ 4\\ 4\\ 4\\ 4\\ 4\\ 4\\ 4\\ 4\\ 4\\ 4\\$	7.88 3.14 0.0072 6.31 0.183 0.827 1.43 1.82 0.588 4.304 0.0007 0.0765 3.054 0.0262 5.48 1.19 0.0033 0.344 0.07 0.0162 0.2028 0.0977 4.2 0.0131 0.2802	Toluene Methylene chloride Benzene Methyl ethyl ketone Butanol Isopropanol Ethyl acetate Methanol Ethyl alcohol Acetone Propanol 1,2-Dichloroethane Trichloroethylene Chloroform 1,1,1-Trichloroethane Perchloroethylene Carbon tetrachloride 1,1,2-Trichloroethane Methyl methacrylate 1,4-Dioxane Ethyl benzene Dichlorobenzene Xylene Toluene diisocyanate Isobutyl alcohol

TABLE J-4. DETAILED FACILITY ANALYSIS: WASTE CHARACTERIZATION BY CONSTITUENT OF CONCERN FOR TSDF SITE 1ª

(continued)

Waste mixture	<u>Surro</u> Hi ^b	gate VPi ^C	Average concentration, %	Constituent
3 3 3 3 3 3 4 4 4	8 8 3 6 4 3 3 7	5 5 6 6 10 12 3 4	0.0111 0.0078 0.292 0.241 0.0073 1.12 0.0001 0.0002	Aniline Methyl acrylate Styrene Methyl isobutyl ketone Formaldehyde Trichlorotrifluoroethane Gasoline Phenols
		Tor	tal organic = 0.14	6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	1 1 1 4 4 4 4 7 2 2 5 5 5 3 3 3 3 3 6 6 6 1 1 1 7 7 7 8 8 3	1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 3 3 3 3	2.43 6.028 0.0055 0.124 0.6097 1.107 4.84 1.32 0.0005 0.0013 0.0006 3.32 0.448 0.0202 0.0025 0.922 2.36 4.23 0.0591 0.0541 0.0541 0.0541 0.0541 0.013 0.281 0.163 0.0754 3.32 0.0005 0.0101 0.216 0.0086 0.006 0.2405	Methylene chloride Toluene Benzene Butanol Isopropanol Ethyl acetate Methyl ethyl ketone Methanol Acetic acid Chlorobenzene Propanol Acetone Ethyl alcohol Chloroform Carbon tetrachloride Perchloroethylene Trichloroethylene 1,1,1-Trichloroethane 1,2-Dichloroethane Methyl methacrylate 1,4-Dioxane 1,1,2-Trichloroethane Ethyl benzene Dichlorobenzene Xylene Phenol Toluene diisocyanate Isobutyl alcohol Aniline Methyl acrylate Styrene

TABLE J-4 (continued)

Waste mixture	<u>Surro</u> Hi ^b	gate VPi ^C	Average concentration, %	Constituent
5 5 5	6 4 3	6 10 12	0.186 0.005 0.866	Methyl isobutyl ketone Formaldehyde Trichlorotrifluoroethane
		Тот	tal organic = 68.2	2
6 6 6 6 6 6	1 5 3 7 9	1 2 3 3 4 6	0.0002 0.0666 0.174 0.0001 0.0002 0.0001 0.0001	Methylene chloride Ethyl acetate Ethyl alcohol Gasoline 1,1,1-Trichloroethane Phenols Cyanide
		Tota	al organic = 0.830)3
7 7	3 7	3 4	0.0001 0.0002	Gasoline Phenols
		Tot	tal organic = 0.14	6
8	9	6	0.267	Cyanide
		Tot	tal organic = 0.38	36
9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	1 1 4 7 5 5 5 3 3 3 3 3 3 6	1 1 1 1 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3	0.0153 0.0552 5.068 0.422 0.0094 0.126 0.0015 0.013 0.0054 0.007 1.69 9.48 0.0558 6.503 0.163 0.733	Benzene Toluene Methylene chloride Isopropanol Methyl ethyl ketone Methanol Propanol Ethyl alcohol Acetone Carbon tetrachloride Perchloroethylene 1,1,1-Trichloroethane Chloroform Trichloroethylene 1,2-Dichloroethane 1,1,2-Trichloroethane

.

Waste mixture	<u>Surro</u> Hi ^b	ogate VPi ^C	Average concentration, %	Constituent
9 9 9 9 9 9 9 9	6 1 1 7 6 3	3 4 4 4 4 6 12	0.0345 0.0083 0.208 0.0074 0.0278 0.0057 2.38	1,4-Dioxane Xylene Dichlorobenzene Ethyl benzene Toluene diisocyanate Methyl isobutyl ketone Trichlorotrifluoroethane
		To	tal organic = 90.4	16
$ \begin{array}{r} 10 \\$	1 4 4 4 7 5 5 3 6 1 1 7 8 8 3 6 4	1 1 1 1 1 2 2 3 3 4 4 5 5 6 6 10	$ \begin{array}{c} 1.38\\ 14.3\\ 2.62\\ 0.334\\ 1.15\\ 11.5\\ 3.22\\ 1.061\\ 7.85\\ 1.86\\ 0.128\\ 0.364\\ 7.82\\ 0.511\\ 0.0142\\ 0.0203\\ 0.532\\ 0.435\\ 0.0133\end{array} $	Methylene chloride Toluene Ethyl acetate Butanol Isopropanol Methyl ethyl ketone Methanol Ethyl alcohol Acetone 1,1,1-Trichloroethane Methyl methacrylate Ethyl benzene Xylene Isobutyl alcohol Methyl acrylate Aniline Styrene Methyl isobutyl ketone Formaldehyde
		Tc	otal organic = 88.5	5
11 11 11 11 11 11 11 11 11 11	1 4 7 2 2 1 1 4 7	1 1 1 2 2 4 4 4 4 4	0.01 0.0082 0.0023 0.0059 0.0037 0.01 0.046 0.0031 0.0001 0.0035	Methylene chloride Toluene Ethyl acetate Methanol Acetic acid Chlorobenzene Ethyl benzene Xylene Benzaldehyde Phenol

Waste mixture	<u>Surrog</u> Hi ^b	ate VPi ^C	Average concentration, %	Constituent
11 11	2 3	5 6	0.0001 0.115	Cumene Styrene
		Tota	al organic = 0.990	5
12 12 12 12 12 12 12	1 4 5 3 3 9	1 1 2 3 3 6	0.0004 0.0387 0.1007 0.0001 0.0004 0.0021	Methylene chloride Ethyl acetate Ethyl alcohol Gasoline 1,1,1-Trichloroethane Cyanide
		Tota	al organic = 0.628	3

TABLE J-4 (continued)

TSDF = Treatment, storage, and disposal facility.

^aThis table presents the average concentrations of specific hazardous constituents of health concern in the waste mixtures handled at TSDF Site 1 for the Detailed Facility Analysis.

 $^{b}H_{i}$ = Henry's law surrogate number keyed to the properties in Table J-1.

 $^{C}VP_{i}$ = Vapor pressure surrogate number keyed to the properties in Table J-1.

		A	queous wast	e concentra	tion (ppm	by weight)		
Henry's law surrogate ^b	Waste mixture 1	Waste mixture 2	Waste mixture 4	Waste mixture 6	Waste mixture 7	Waste mixture 8	Waste mixture 11	Waste mixture 12
MHL8	312	122	41	236	41	ø	55	142
HHL8	280	54	269	592	269	ø	3.640	948
LHMB	2.040	2.450	89	192	89	3.610	1.320	61
мнмв	4.56Ø	3.170	301	6.210	3Ø1	247	226	4.120
HHMB	633	48	754	403	754	Ø	1.180	618
LHHB	1	1	2	1	2	ø	573	ø
мннв	361	352	ø	666	ø	ø	202	387
нннв	1	Ø	ø	2	ø	Ø	2,770	4
Total	8,190	6,200	1,46Ø	8,300	1,460	3,860	9,970	6,280
	Oily wa	ste concentr	ation (ppm	by weight)	-			
Vapor pressure surrogate ^b	Waste mixture 3	Waste mixture 5	Waste mixture 9	Waste mixtur 10	8			
н∨нв	225.000	172.000	59.000	360.000				
HVMB	84.300	64.300	40,000	149,000				
HVLB	239.000	185.000	475.000	28,300				
MVHB	67,400	51,100	10.600	114.000				
MVMB	82,200	63,600	98,900	65,300				
MVLB	43,600	32,500	16,900	65,100				
LVMB	138,000	103,000	177,000	99,700				
VHVHB	3 160	2 450	1 950	4 080				

TABLE J-5. DETAILED FACILITY ANALYSIS: AVERAGE CONCENTRATIONS OF SURROGATES IN WASTE STREAM MIXTURES AT TSDF SITE 1ª

TSDF = Treatment, storage, and disposal facility.

2,450

8,890

683,000

3,160

11,500

894,000

^{'a}This table presents the average concentrations of surrogates based on Henry's law constants (for aqueous wastes) and vapor pressure (for oily wastes). Surrogates are defined in Appendix D. Section D.2.3.3.

4,080

885,000

ø

1,950

24,500

904,000

^bSurrogate codes:

VHVLB

Total

MHLB = Medium Henry's law, low biodegradation.

- HHLB = High Henry's law, low biodegradation.
- LHMB = Low Henry's law, medium biodegradation.

MHMB = Medium Henry's law, medium biodegradation.

HHMB .= High Henry's law, medium biodegradation.

LHHB = Low Henry's law, high biodegradation.

MHHB = Medium Henry's law, high biodegradation.

HHHB = High Henry's law, high biodegradation.

HVHB = High volatility, high biodegradation.

HVMB = High volatility, medium biodegradation.

HVLB = High volatility, low biodegradation.

MVHB = Medium volatility, high biodegradation.

MVMB = Medium volatility, medium biodegradation.

MVLB = Medium volatility, low biodegradation.

LVMB = Low volatility, medium biodegradation.

VHVHB = Very high volatility, high biodegradation.

VHVLB = Very high volatility, low biodegradation.

Variables	Definitions
Q	Throughput
N	Turnovers/year
$ ho_{waste}$	Density of waste
^{MW} waste	Molecular weight of waste
D	Diameter
Н	Height
POWR	Total power to aerator
At	Area affected by aeration
d	Impeller diameter, m
ω	Rotational speed of impeller
d*	Impeller diameter, ft
Aq	Quiescent area
٩t	Total operating pressure
А	Area
$ ho_{L}$	Density of water
MW _{oil}	Molecular weight of oily waste
1	Length of uncovered dumpster or fixation pit
W	Width of uncovered dumpster
U	Windspeed

TABLE J-6. DETAILED FACILITY ANALYSIS: DEFINITION OF VARIABLES USED IN SHORT-TERM TSDF EMISSION EQUATIONS^a

TSDF = Treatment, storage, and disposal facility.

^aThis table presents those variables used to estimate short-term organic emissions from TSDF. The emission equations (given in Reference 2) are modified versions of the long-term equations defined in Reference 1.

Spills	Spill fraction during drum transfer to storage = 1×10^{-4} . Q = 2.40 x 10^{-4} m ³ /s. Assume only 50 percent of the organics in the spill is volatilized to the atmosphere. Spills occur 8 h each day.
Drum and Tank Truck Loading	Q = $6.72 \times 10^{-3} \text{ m}^{3}/\text{s}$ (for two tank trucks).
Tank Loading	Q = 2.40 x 10 ⁻⁴ m ³ /s for three tanks (from drum to storage tank) N = 47. MW _{waste} = 18 g/g mol.
Tank Storage	D = 3.0 m, H = 1.2 m.

Use the Henry's law surrogate table (Table J-1) for all of the above equations.

J.2.2.1.2 <u>Acid/alkali receiving area (emission source No. 2)</u>. The acid/alkali receiving area consists of six covered $41-m^3$ storage tanks (3.7 m x 3.7 m x 3 m).

Each week, six $30-m^3$ tank trucks deliver acidic and caustic waste to the acid/alkali receiving area. Tank loading occurs daily at 0900 hours for 1 h at a rate of 6.50 x 10^{-3} m³/s.

Pumping and Piping Refer to Table 3 in Reference 2.

Tank Loading	Q = 2.40 x 10^{-4} m ³ /s, N = 33 (for two tanks). Q = 6.5 x 10^{-3} m ³ /s, N = 56 (for four tanks).
Tank Storage	D = 3.7 m, H = 1.8 m.

Use the Henry's law surrogate table (Table J-1) for all the above equations.

J.2.2.1.3 <u>North equalization basin (emission source No. 3)</u>. For 8 h each day, waste from the acid/alkali receiving area is pumped to the North equalization basin (an uncovered, aerated tank). Wastewater from the oil treatment system and washwater and filtrate from the rotary vacuum filters are pumped 8 h each day to the North equalization basin.

Pumping and Piping Refer to Table 3 in Reference 2.

Mechanically Aerated Uncovered Tank	POWR = 14.9 kW (20 hp), $A_t = 16.7 m^2$, retention time = 12 h, d = 1.524 m, w = 0.93 rad/s, d [*] = 1.524 m, $A_q = 66.8 m^2$,
	7.7 m x 10.8 m x 2.3 m, Q = 5.10 x 10^{-3} m ³ /s.

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.2.1.4 <u>South waste receiving area (emission source No. 4)</u> Each week, the contents of four 26.5-m^3 tank trucks are pumped into the South waste receiving area, which consists of four covered 30.3-m^3 (8,000-gal) storage tanks (3.7 m x 3.7 m x 3 m). One tank truck contains acid/chrome waste, two tank trucks contain acid/ alkali dilute sludge, and one tank truck contains cyanide. Each type of waste is stored in a separate storage tank. Tank loading occurs early Thursday at 0900 hours each week for 1 h at a rate of $2.89 \times 10^{-2} \text{ m}^3/\text{s}$.

Pumping and Piping	Refer to Table 3 in Reference 2.
Tank Loading	Q = 2.89 x 10^{-2} m ³ /s, N = 36.
Tank Storage	D = 3.7 m, H = 1.4 m.

Use the Henry's law surrogate table (Table J-1) for all of the above equations.

J.2.2.1.5 <u>Cyanide pretreatment (emission source No. 5)</u>. Cyanide is pumped from the South waste receiving area to the uncovered, quiescent cyanide pretreatment tank (5 m x 6 m x 3 m) each day for 8 h.

Pumping and Piping Refer to Table 3 in Reference 2.

Flow-through $A = 30 \text{ m}^2$, D = 3 m, $Q = 1.29 \times 10^{-4} \text{ m}^3/\text{s}$. Uncovered Tank

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.2.1.6 <u>Chrome reduction</u> (emission source No. 6). The acid/chrome waste is pumped from the South waste receiving area to the uncovered, quiescent chrome reduction tank (5 m x 6 m x 3 m) each day for 8 h.

Pumping and Piping Refer to Table 3 in Reference 2.

Flow-through $A = 30 \text{ m}^2$, D = 3 m, $Q = 1.29 \times 10^{-4} \text{ m}^3/\text{s}$. Uncovered Tank

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.2.1.7 <u>Neutralization tank (emission source No. 7)</u>. The acid/alkali dilute sludge and the reduced acid/chrome waste are pumped to the uncovered, quiescent neutralization tank (7 m x 10 m x 5 m) each day for 8 h.

Pumping and Piping Refer to Table 3 in Reference 2.

Flow-through $A = 70 \text{ m}^2$, D = 5 m, $Q = 3.87 \times 10^{-4} \text{ m}^3/\text{s}$. Uncovered Tank

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.2.1.8 <u>South equalization basin (emission source No. 8)</u>. The contents of the neutralization tank along with the pretreated cyanide waste are pumped into the South equalization basin--an uncovered, aerated tank (6.9 m x 15.8 m x 2.2 m). Pumping occurs each day for 8 h at a rate of 1.13 m³/s. The contents of the North equalization basin are pumped into the South equalization basin along with neutralization chemicals at a flow rate of 5.10 x 10^{-3} m³/s for 8 h each day.

Pumping and Piping Refer to Table 3 in Reference 2.

Mechanically	POWR = 22.4 kW (30 hp), A _t = 10.9 m ² ,
Aerated Uncovered	retention time = 12 h, d = 1.067 m, ω = 1.13
Tank	rad/s , $A_{\rm c} = 97.8 \text{ m}^2$, 6.8 m x 15.8 m x 2.2 m,
	$Q = 6.23^{T} \times 10^{-3} \text{ m}^{3}/\text{s}$.

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.2.1.9 <u>Aqueous waste clarifier (emission source No. 9)</u>. The contents of the South equalization basin are pumped into the aqueous waste clarifier--an uncovered, quiescent treatment tank (6.9 m x 15.8 m x 2.2 m). Pumping occurs for 8 h each day.

Pumping and Piping Refer to Table 3 in Reference 2.

Flow-through $A = 108.7 \text{ m}^2$, D = 2.2 m, $Q = 6.23 \times 10^{-3}$ Uncovered Tank m^3/s Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.2.1.10 <u>Rotary vacuum filters (emission source No. 10)</u>. Waste from the aqueous waste clarifier is pumped to the rotary vacuum filters at a rate of 2.50 x 10^{-3} m³/s. The vacuum filter operates continuously from 0800 to 1600 hours. The vacuum generates 68.8 m³ of filter cake each week.

Pumping and Piping Refer to Table 3 in Reference 2.

Vacuum Pump $P_t = 40 \text{ kPa}, (0.4 \text{ atm}), Q_t = 11.2 \text{ m}^3.$

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.2.1.11 <u>Sludge loading area (emission source No. 11)</u>. Filter cake from the rotary vacuum is generated at a rate of 19.7 m³ every 2 days. Filters are loaded on an open dump truck and hauled to an offsite landfill.

Vacuum Filer Cake L = 3.0 m, W = 2.5 m.

Use the Henry's law surrogate table (Table J-1) for the above equation.

J.2.2.1.12 <u>Receiving tank 8 (emission source No 12)</u>. Each day, industrial waste oils from one $18.9-m^3$ tank truck and oily wastewater (nonhazardous waste) from two $26.5-m^3$ tank trucks are pumped into receiving tank 8, which consists of four $19-m^3$ (5,000-gal) treatment tanks--uncovered and quiescent (3 m x 3 m x 2.5 m deep). Pumping duration is 23 m³ for 8 h each day. Hazardous waste is transferred at a rate of $5.1 \times 10^{-4} \text{ m}^3/\text{s}$ for 8 h each day.

Pumping and Piping Refer to Table 3 in Reference 2.

Oil Film Surface $A = 37.16 \text{ m}^2$, $\rho_L = 8.8 \times 10^5 \text{ g/m}^3$, $MW_{\text{oil}} = 100 \text{ g/g mol}$.

Use the vapor pressure surrogate table (Table J-1) for each of the above equations.

J.2.2.1.13 <u>Recovered waste oil storage tank (emission source no. 13)</u>. Recovered waste oil from receiving tank 8 is pumped to the recovered waste oil storage tank (3.7 m long x 1.8 m diameter) along with waste oil containing flammable solvents from the waste oil storage tank (3 m x 3 m x 2.5 m) each week. The storage tank is covered and vented. Pumping rate is $1.32 \times 10^{-4} \text{ m}^3/\text{s}$ for 8 h each day from Section 0.2.2.1.12, Receiving tank 8. The recovered waste oil is blended and used as secondary fuel.

Pumping and PipingRefer to Table 3 in Reference 2.Tank Loading $Q = 1.23 \times 10^{-3} \text{ m}^3/\text{s}$, N = 48.Tank StorageAssume $\rho_{waste} = 8.8 \times 10^5 \text{ g/m}^3$, $MW_{waste} = 100 \text{ g/g mol}$, D = 4.0 m, H = 2.0 m.

Use the vapor pressure surrogate table (Table J-1) for each of the above equations.

J.2.2.1.14 <u>Reusable chlorinated solvent storage tank (emission source</u> <u>No. 14</u>). Each day, reusable chlorinated solvents are pumped at a rate of 8.45 x 10^{-6} m³/s from receiving tank 8 to the 6.8-m³ chlorinated solvent storage tank (a covered tank 2 x 2.3 m in diameter). Pumping duration is 8 h each day. Once a month, chlorinated solvents are sent offsite for reclamation.

Pumping and Piping Refer to Table 3 in Reference 2.

Tank Loading $Q = 8.45 \times 10^{-6} \text{ m}^3/\text{s}$, N = 13.

Tank Storage Assume $MW_{waste} = 100 \text{ g/g mol}, D = 2.3 \text{ m}, H = 1.1 \text{ m}.$

Use the vapor pressure surrogate table (Table J-1) for each of the above equations.

J.2.2.1.15 <u>Waste oil storage tank (emission source No. 15)</u>. Each week, the contents of 90 drums are pumped into an 18.9-m^3 waste oil storage tank (3 m x 3 m x 2.5 m). The storage tank is covered and vented and is located in the drum storage and transfer building.

Pumping and Piping Refer to Table 3 in Reference 2.

Spills	Spill fraction during drum transfer to storage = 1×10^{-4} . Q = 9.29 x 10^{-5} m ³ /s.
Tank Loading	Q = 9.29 x 10^{-5} m ³ /s. N = 51. ρ_{waste} = 8.8 x 10^{5} g/m ³ , MW _{waste} = 100 g/g mol.

Tank Storage

D = 3.0 m, H = 1.2 m.

Use the vapor pressure surrogate table (Table J-1) for each of the above equations.

J.2.3 Description of Site 2

Site 2 is a commercial hazardous waste treatment and disposal facility. A variety of hazardous and nonhazardous wastes are accepted at the facility. Common wastes received include wastes from chemical, steel, and automotive industries. Of specific interest are the following activities: active landfills, wastewater treatment (including uncovered tanks and surface impoundments), and drum transfer and processing. The plot plan with numbered emission sources and a flow diagram for Site 2 are shown in Figures J-3 and J-4, respectively. The flow diagram contains alphabetized process flows that are keyed to short-term and continuous (annual average) flow rates as shown in Table J-7.

Table J-8 gives the contents (waste form and code) of each waste mixture managed at Site 2. The average concentrations of waste constituents of a health concern in each waste stream mixture are shown in Table J-9; average waste compositions expressed as organic surrogates are listed in Table J-10. Design and operating parameters for the site along with the appropriate emission calculations are described in the following section.

J.2.3.1 <u>Design and Operating Parameters of Emission Points for Site 2</u>. The following pages present the design and operating parameters of Site 2 emission sources for estimating both long-term and short-term emissions. Each numbered emission source is identified in the plot plan as shown in Figure J-3. Table J-6 presents the definitions of variables listed for each emission source when estimating short-term emissions.

J.2.3.1.1 <u>Drum storage and transfer building (emission source No. 1)</u>. Five hundred 0.21-m³ drums containing aqueous waste arrive each week. The contents of these drums are stored in a 90.8-m³ covered storage tank (4.8 m x 4.8 m x 4 m). It is assumed that each drum contains 15 percent solids.

Pumping and Piping Refer to Table 3 in Reference 2.

Spills Spill fraction during drum transfer to storage = 1×10^{-4} , Q = $4.80 \times 10^{-4} \text{ m}^3/\text{s}$. (Assume only 50 percent of the organics in the spill is volatilized to the atmosphere.)



Figure J-3. Detailed facility analysis plot plan of Site 2.



Figure J-4. Site 2 flow diagram.

J-30

Process flow path ^b	Short-term flow rates, ^c 10-3 m ³ /s	Short-term timeframe	Continuous flow rates,d 10-3 m3/s
A. B. C. D. E. F. G. H. I. J. K. L. M. N. O. P. Q. R. S. T.	0.48 0.253 3.84 24 21.5 21.5 21.5 21.5 21.4 0.094 21.4 21.4 21.4 66.0 21.4 21.4 21.4 21.4 0.094 21.3 21.3 59 m ³ /mo 59 m ³ /mo	(7 d/wk, 8 h/d) (1 d/wk, 8 h/d) (7 d/wk, 1 h/d) (7 d/wk, 8 h/d) (1 h/wk) (7 d/wk, 8 h/d) (7 d/wk, 8 h/d) (1 h/mo)	$\begin{array}{c} 0.160\\ 0.0264\\ 0.160\\ 7.01\\ 7.17\\ 7.17\\ 7.17\\ 7.17\\ 7.13\\ 0.0314\\ 7.13\\ 0.392\\ 0.392\\ 7.52\\ 7.52\\ 7.52\\ 7.52\\ 7.52\\ 7.52\\ 7.52\\ 0.0314\\ 7.49\\ 7.49\\ 0.0228\\ 0.0228\end{array}$

TABLE J-7. DETAILED FACILITY ANALYSIS: SHORT-TERM AND CONTINUOUS PROCESS FLOW RATES WITHIN TSDF SITE 2^a

TSDF = Treatment, storage, and disposal facility.

^aThis table presents short-term and continuous flow rates that are based on site-specific information.

^bHazardous waste management process flow paths are alphabetized to correspond to Figure J-4.

^cShort-term flow rates were estimated based on site-specific information.

^dContinuous flow rates used to estimate long-term emissions were estimated given nonstop flow through the facility 7 d/wk, 24 h/d.

Waste mixture number: ^b	1	2	3	4	5	6
Percent comp. by waste form: ^C	7% 2XX 93% 3XX	100% 1XX	100% 3XX	20% 2XX 65% 3XX 15% 5XX	100% 3XX	100% 1XX
RCRA waste code within each waste form: ^d	D002 D005 F009 K062 U210	D002 D005 F009 K062 U210	D002 D005 F009 K062 U210	D002 D003 D004 D005 D006 D007 D008 D009 D010 D011 F009 K002 K049 K050 K051 K052 K062 P015 P030 U009 U012 U036 U037 U009 U012 U036 U037 U036 U037 U080 U102 U122 U124 U125 U124 U125 U124 U125 U134 U144 U147 U151 U159 U189 U207 U210 U228	D002 D003 D004 D005 D006 D007 D008 D009 D010 D011 F009 K002 K049 K050 K051 K052 K062 P015 P030 U009 U012 U036 U037 U080 U102 U122 U124 U125 U124 U125 U124 U125 U124 U125 U124 U125 U124 U125 U124 U125 U124 U125 U134 U147 U151 U159 U189 U207 U210 U211 U220 U228	D002 D003 D004 D005 D006 D007 D008 D009 D010 D011 F009 K002 K049 K050 K051 K052 K062 P015 P030 U009 U012 U036 U037 U080 U102 U122 U124 U125 U134 U125 U134 U125 U134 U144 U147 U151 U159 U189 U207 U210 U211 U220 U228

TABLE J-8. DETAILED FACILITY ANALYSIS: CONTENTS OF EACH WASTE MIXTURE MANAGED AT TSDF SITE 2ª

(continued)

RCRA = Resource Conservation and Recovery Act. TSDF = Treatment, storage, and disposal facility. 1XX = Inorganic solid. 2XX = Aqueous sludge. 3XX = Aqueous liquid. 5XX = Organic sludge/solid.

^bWaste stream numbers correspond to the mixture of RCRA waste codes and their forms that enter waste management units at TSDF Site 2. These streams are labeled in Figure J-4.

^CA waste stream may be a mixture of two or more physical/chemical waste forms of a RCRA waste code. These forms are described in Appendix D, Section D.2.2.

dRCRA waste codes are defined in 40 CFR 261, Subparts C and D.

Waste	Surro	gate	Average concentration,	
mixture	Hiu	VPic	%	Constituent
1 1 1 1 1 1 1 1 1 1 1	1 4 7 2 5 5 3 9	1 1 1 2 2 2 2 3 3	0.0012 0.0002 0.0002 0.005 0.0013 0.0001 0.0011 0.0002 0.0002 0.0002 0.0008	Methylene chloride Methyl ethyl ketone Isopropanol Methanol Acetic acid Benzene, Chloro Vinyl acetate Acetone 1,2-Dichloroethane Formic acid
1 1 1 1 1 1 1 1 1 1 1	9 9 1 7 8 3 6 9 7 4 3	3 4 4 5 6 6 6 8 10 12	0.0001 0.0038 0.0005 0.0116 0.0002 0.0054 0.0003 0.0003 0.0004 0.0001	Ethyl glycol Hydrazine Xylene Phenol Aniline p-Chloroaniline Dimethyl formamide Glycidol Glycerin Formaldehyde Bromomethane
		To	otal organic = 0.2	
2 2 2	1 3 2	1 3 5	0.0003 0.0253 0.0003	Benzene Carbon tetrachloride Cumene
		Tot	al organic = 1.12	
3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	1 4 7 2 5 5 5 3 9 9 9	1 1 1 2 2 2 2 3 3 3 3 3 3	0.0012 0.0002 0.002 0.005 0.0013 0.0001 0.0011 0.0002 0.0002 0.0002 0.0008 0.0001 0.0001	Methylene chloride Methyl ethyl ketone Isopropanol Methanol Acetic acid Benzene chloro Vinyl acetate Acetone 1,2-Dichloroethane Formic acid Ethyl glycol Hydrazine

TABLE J-9. DETAILED FACILITY ANALYSIS: WASTE CHARACTERIZATION BY CONSTITUENT OF CONCERN FOR TSDF SITE 2^a

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(continued)

Wasto	Surro	ogate	Average	
mixture	Hib	VPiC		Constituent
3 3 3 3 3 3 3 3 3 3 3	1 7 8 3 6 9 7 4 3	4 5 6 6 8 10 12	0.0038 0.0005 0.0116 0.0002 0.0054 0.0003 0.0003 0.0004 0.0001	Xylene Phenol Aniline p-Chloroaniline Dimethyl formamide Glycidol Glycerin Formaldehyde Bromomethane
		Ţ	otal organic = 0.2	2
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1 1 4 4 4 7 2 2 5 5 5 5 3 3 3 6 9 9 9 1 1 7 5 5 8 8 3 3 6 9	1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	0.0001 0.0142 0.0012 0.0002 0.0014 0.0367 0.0087 0.0004 0.0003 0.0069 0.0002 0.0016 0.0004 0.0016 0.0004 0.0016 0.0002 0.0072 0.392 0.0002 0.0072 0.392 0.0008 0.002 0.00243 0.002 0.00243 0.002 0.00243 0.0056 0.0003 0.0002 0.0742 0.113 0.0001 0.0009 0.0347 0.0206	Toluene Methylene chloride Isopropanol Acrylonitrile Methyl ethyl ketone Methanol Acetic acid Benzene, Chloro N-propanol Vinyl acetate Ethanol Acetone Trichloroethylene 1,2-Dichloroethane Tetrachloroethene Carbon tetrachloride 1,4-Dioxane Formic acid Ethylene glycol Hydrazine Dichlorobenzene Xylene Phenol Acetophenone Methacrylic acid (MAA) Aniline Phthalic anhydride 1,2,3-Trichloropropane P-Chloroaniline Dimethyl formamide

TABLE J-9 (continued)

Waste mixture	<u>Surra</u> Hj ^b	ogate VPi ^C	Average concentration, %	Constituent
4 4 4 4 4 4	9 7 8 4 2 3	6 8 9 10 11 12	0.0016 0.0016 0.0001 0.0855 0.0037 0.0006	Glycidol Glycerin Maleic anhydride Formaldehyde Diethyl amine Bromomethane
		То	tal organic = 6.17	,
555555555555555555555555555555555555555	4 7 2 2 5 5 3 9 9 9 1 8 3 6 9 7 4 2 3	1 1 2 2 2 2 2 3 3 3 3 3 3 3 3 3 3 3 4 5 6 6 6 8 10 11 12	0.0002 0.0043 0.0014 0.001 0.0003 0.0011 0.0003 0.0001 0.0001 0.0001 0.0001 0.002 0.0003 0.0003 0.0003 0.0004 0.0004 0.0004 0.0004 0.0001	Isopropanol Methyl ethyl ketone Methanol Acetic acid Benzene, Chloro Acetone Vinyl acetate 1,2-Dichloroethane Formic acid Ethylene glycol Hydrazine Xylene Aniline p-Chloroaniline Dimethyl formamide Glycidol Glycerin Formaldehyde Diethyl amine Bromomethane
Total organic = 0.198				
5 6 6 6	1 4 3 2	1 1 3 5	0.0003 0.0015 0.0261 0.003	Benzene Isopropanol Carbon tetrachloride Cumene
Total organic = 1.2214				

TABLE J-9 (continued)

TSDF = Treatment, storage, and disposal facility.

^aThis table presents the average concentrations of specific hazardous constituents of health concern in the waste mixtures handled at TSDF Site 2 for the Detailed Facility Analysis.

 $^{b}H_{i}$ = Henry's law surrogate number keyed to the properties in Table J-1. $^{C}VP_{i}$ = Vapor pressure surrogate number keyed to the properties in Table J-1.

			Concentra	tion, ppm	by weight	
Henry's law surrogateb	Waste mixture 1 and 3	Aqueous Waste mixture 2	waste Waste mixture 5	Waste mixture 6	Vapor pressure surrogate ^t	Oily waste Waste mixture 4
MHLB HHLB LHMB MHMB HHMB LHHB MHHB HHHB	236 223 495 738 121 79 18 93	2,190 2,900 4,630 1,390 3 48 0 3	254 212 521 707 130 68 21 87	2,190 3,230 4,760 1,580 67 249 132 11	HVHB HVMB HVLB MVHB MVMB MVLB LVMB VHVHB VHVHB	565 1,340 6,470 424 8,810 2,050 37,900 1,320 656
Total	2,000	11,200	2,000	12,200		59,500

TABLE J-10. DETAILED FACILITY ANALYSIS: AVERAGE CONCENTRATIONS OF SURROGATES IN WASTE STREAM MIXTURES AT TSDF SITE 2ª

TSDF = Treatment, storage, and disposal facility.

^aThis table presents the average concentrations of surrogates based on Henry's law constants (for aqueous wastes) and vapor pressure (for oily wastes). Surrogates are defined in Appendix D, Section D.2.3.3.

^DSurrogate codes:

MHLB = Medium Henry's law, low biodegradation. HHLB = High Henry's law, low biodegradation. LHMB = Low Henry's law, medium biodegradation. MHMB = Medium Henry's law, medium biodegradation. HHMB = High Henry's law, medium biodegradation. LHHB = Low Henry's law, high biodegradation. MHHB = Medium Henry's law, high biodegradation. HHHB = High Henry's law, high biodegradation. HVHB = High volatility, high biodegradation. HVMB = High volatility, medium biodegradation. HVLB = High volatility, low biodegradation. MVHB = Medium volatility, high biodegradation. MVMB = Medium volatility, medium biodegradation. MVLB = Medium volatility, low biodegradation. LVMB = Low volatility, medium biodegradation. VHVHB = Very high volatility, high biodegradation. VHVLB = Very high volatility, low biodegradation.

Tank Loading $Q = 4.8 \times 10^{-4} \text{ m}^3/\text{s}$ (from drum to storage tank) N = 56, MW_{waste} = 18 g/g mol. Tank Storage D = 5.4 m, H = 2.0 m.

Use the Henry's law surrogate table (Table J-1) for all of the above equations.

J.2.3.1.2 <u>L1 - Tank storage (emission source No. 2)</u>. Each day at 0900 hours, aqueous waste is pumped from the 90.8-m³ storage tank to L1, a 2,271-m³ covered storage tank (15 m x 15 m x 10 m) for 1 h at a rate of $3.84 \times 10^{-3} \text{ m}^3/\text{s}$.

Each day, twenty 30.3-m^3 tank trucks deliver aqueous waste to tank L1 at the wastewater facility. Waste from the tank trucks is loaded into storage tank L1 daily beginning at 0800 hours for 8 h at a rate of 2.40 x $10^{-2} \text{ m}^3/\text{s}$.

Pumping and Piping Refer to Table 3 in Reference 2.

Tank Loading	$Q = 3.84 \times 10^{-3} \text{ m}^{3}/\text{s}$	(from aqueous storage
	tank to tank Ll)	
	$Q = 2.40 \times 10^{-2} \text{ m}^3/\text{s}$	(from tank trucks to
	tank L1)	
	$N = \pm 00$.	

Tank Storage D = 17 m, H = 5.0 m.

Use the Henry's law surrogate table (Table J-1) for all of the above equations.

J.2.3.1.3 <u>LR - Neutralization tank (emission source No. 3)</u>. The aqueous waste is pumped from tank L1 to tank LR (uncovered, quiescent) for neutralization. Pumping occurs for 8 h each day at a rate of 2.15 x 10^{-2} m³/s.

Pumping and Piping Refer to Table 3 in Reference 2.

Flow-through $A = 38.4 \text{ m}^2$, d = 5 m, $Q = 2.15 \times 10^{-2} \text{ m}^3/\text{s}$. Uncovered Tank

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.3.1.4 <u>L2 - Surface impoundment (emission source No. 4)</u>. The neutralized waste is pumped to L2, a $1,325-m^3$ quiescent surface impoundment. Pumping occurs for 8 h each day at a rate of 2.15 x 10^{-2} m³/s.

Pumping and Piping Refer to Table 3 in Reference 2.

Flow-through A = 121 m², D = 11 m, Q = $2.15 \times 10^{-2} \text{ m}^3/\text{s}$. Surface Impoundment

Use the Henry's law surrogate table (Table J-1) for all of the above equations.

J.2.3.1.5 <u>Filter press (emission source No. 5)</u>. Waste is pumped from the L2 surface impoundment to the filter press at a rate of 2.15 x 10^{-2} m³/s for 8 h each day. Solids trapped by the filter (2.4 m x 9 m) are collected in an open dump truck and taken to an active landfill (see Section 0.2.3.1.20). Solids are generated at a rate of approximately 9.4 x 10^{-5} m³/s for 8 h each day.

Pumping and Piping Refer to Table 3 in Reference 2.

Vacuum Filter Cake 1 = 3.04 m, w = 2.44 m.

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.3.1.6 <u>L3 - Aerated surface impoundment (emission source No. 6)</u>. Waste is pumped from the filter press to the aerated surface impoundment at a rate of 2.14 x 10^{-2} m³/s for 8 h each day.

Pumping and Piping Refer to Table 3 in Reference 2.

Mechanically	POWR = 14.9 kW (20 hp), $A_t = 45 \text{ m}^2$, retention
Aerated Surface	time = 12 h.
Impoundment	$d = 1.524 \text{ m}, \omega = 0.93 \text{ rad/s}, A_0 = 180 \text{ m}^2$,
	15 m x 15 m x 6 m, Q = 2.14 x 10 ⁻² m ³ /s.

Use the Henry's law surrogate table (Table J-1) for all of the above equations.

J.2.3.1.7 <u>L4 - Surface impoundment (emission source No. 7)</u>. Waste is pumped from surface impoundment L3 to the quiescent surface impoundment L4 at a rate of 2.14 x 10^{-2} m³/s for 8 h each day.

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Pumping and Piping Refer to Table 3 in Reference 2. $A = 225 \text{ m}^2$, $Q = 2.14 \times 10^{-2} \text{ m}^3/\text{s}$, D = 6 m. Flow-through Surface Impoundment Use the Henry's law surrogate table (Table J-1) for all of the above equations. J.2.3.1.8 L5 - Storage tank (emission source No. 8). L5, a 1,136-m³ covered storage tank, receives leachate from the closed landfills (SCMF 1, 2, 3, and 4). Leachate is pumped to L5 each Monday at 0900 hours for 1 h. Pumping and Piping Refer to Table 3 in Reference 2. $0 = 6.60 \times 10^{-2} \text{ m}^3/\text{s}.$ Tank Loading D = 15.5 m, H = 3.0 m, N = 11.Tank Storage Use the Henry's law surrogate table (Table J-1) for all of the above equations. J.2.3.1.9 L6 - Storage tank (emission source No. 9). Each week, leachate is pumped from tank L5 to tank L6 (a covered tank) for 1 h at a rate of 6.6 x 10^{-2} m³/s. Waste is pumped from surface impoundment L4 to storage tank L6 at a rate of 2.14 x 10^{-2} m³/s for 8 h each day. Pumping and Piping Refer to Table 3 in Reference 2. $Q = 6.6 \times 10^{-2} \text{m}^{3}/\text{s}$ (from tank L5). Tank Loading $Q = 2.14 \times 10^{-2} \text{ m}^3/\text{s}$ (from surface impoundment L4). Tank Storage D = 15.5 m, H = 3.0 m, N = 198. Use the Henry's law surrogate table (Table J-1) for all of the above equations. J.2.3.1.10 L7 - Surface impoundment (emission source No. 10). Waste

is pumped from tank L6 to aerated surface impoundment L7 for 8 h each day at a rate of 2.14 x 10^{-2} m³/s.

Pumping and Piping Refer to Table 3 in Reference 2. Mechanically POWR = 14.9 kW (20 hp), $A_t = 37.7 m^2$, d = 1.524 m, ω = 0.93 rad/s, A_q = 150.9 m². 15.5 m diameter x 6 m high, Q = 2.14 x 10⁻² m³/s. Use the Henry's law surrogate table (Table J-1) for all of the above equations.

J.2.3.1.11 <u>L8 - Neutralization tank (emission source No. 11)</u>. Waste is pumped from surface impoundment L7 to the uncovered, quiescent neutralization tank L8 for 8 h each day at a rate of 2.14 x 10^{-2} m³/s.

Pumping and Piping Refer to Table 3 in Reference 2. Flow-through $A = 188.7 \text{ m}^2$, D = 6 m, $Q = 2.14 \times 10^{-2} \text{ m}^3/\text{s}$. Uncovered Tank

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.3.1.12 <u>Sand filters (emission source No. 12)</u>. Waste is pumped from the neutralization tank to the sand filters at a rate of 2.14 x 10^{-2} m³/s for 8 h each day. Solids trapped by the filter (2.4 m x 9.1 m) are collected in an open dump truck and taken to the landfill. Solids are generated at a rate of 9.4 x 10^{-5} m³/s for 8 h each day.

Pumping and Piping Refer to Table 3 in Reference 2.

Vacuum Filter Cake 1 = 3.04 m, w = 2.44 m.

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.3.1.13 <u>L9 - Surge tank (emission source No. 13)</u>. Liquid waste from the sand filters is pumped to the 1,136-m³ uncovered, quiescent surge tank at a rate of 2.13 x 10^{-2} m³/s for 8 h each day.

Pumping and Piping Refer to Table 3 in Reference 2.

Tank Loading $Q = 2.13 \times 10^{-2} \text{ m}^3/\text{s}$, N = 197.

Tank Storage D = 15.5 m, H = 3.0 m.

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.3.1.14 <u>L10 - Surface impoundment (emission source No. 14)</u>. Waste from the surge tank is pumped to the aerated L10 surface impoundment at a rate of 2.13 x 10^{-2} m³/s for 8 h each day.

Pumping and Piping Refer to Table 3 in Reference 2.

Mechanically	POWR = 30 kW (40 hp),	$A_t = 37.7 m^2$,
Aerated Surface	d = $1.524 \text{ m}, \omega = 0.93$	rad/s, $A_q = 150.9 m^2$,
Impoundment	15.5 m diameter x 6 m m^{3}/s .	high, $Q = 2.13 \times 10^{-2}$

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.3.1.15 <u>L11 - Surface impoundment (emission source No. 15)</u>. Waste from the L10 surface impoundment is pumped to aerated impoundment L11, a 1,136-m³ surface impoundment, at a rate of 2.13 x 10^{-2} m³/s for 8 h each day.

Pumping and Piping Refer to Table 3 in Reference 2.

POWR = 14.9 kW (20 hp), $A_t = 37.7 \text{ m}^2$,
$d = 1.524 \text{ m}, \omega = 0.93 \text{ rad/s}, A_0 = 150.9 \text{ m}^2$
15.5 m diameter x 6 m high, Q $=$ 2.13 x 10 ⁻² m ³ /s.

Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.3.1.16 <u>L12 - Surface impoundment (emission source No. 16)</u>. Waste is pumped from L11 surface impoundment to the aerated impoundment L12, a 1,136-m³ surface impoundment, at a rate of 2.13 x 10^{-2} m³/s for 8 h each day.

Pumping and Piping Refer to Table 3 in Reference 2.

Mechanically	POWR = 14.9 kW (20 hp), $A_{+} = 37.7 \text{ m}^2$,
Aerated Surface	$d = 1.524 \text{ m}, w = 0.93 \text{ rad/s}, A_{ff} = 150.9 \text{ m}^2$
Impoundment	15.5 m diameter x 6 m high, $Q = 2.13 \times 10^{-2}$ m ³ /s
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Use the Henry's law surrogate table (Table J-1) for each of the above equations.

J.2.3.1.17 <u>Discharge (emission source No. 17)</u>. Liquids from the L12 surface impoundment are pumped offsite.

J.2.3.1.18 <u>Closed landfills (emission source No. 18)</u>. Emissions from closed landfills are not included because of a lack of information on waste

concentrations within the source and the difficulty of modeling this source. In addition, closed landfills are not currently included in the Detailed Facility Modeling effort.

J.2.3.1.19 <u>Waste fixation pits (emission source No. 19)</u>. On the first Monday of each month at 1000 hours, two tank trucks, each containing 20 m³ aqueous sludge slurry, are emptied into fixation pit A. On the first Monday of each month at 1100 hours, one tank truck containing 19 m³ organic sludge slurry is emptied into fixation pit B. Each pit has a 1-h fixation time. This facility encloses two fixation pits (4 m x 3 m x 3 m) that operate at ambient temperature. The entire building is evacuated through the two particulate scrubber units, which have stacks 17 m tall and 1.2 m in diameter. The building is 15 m tall. The scrubbers exhaust 21 m³/s each and operate simultaneously and continuously.

Fixation Pit 1 = 4.0 m, w = 3.0 m, U = 0.045 m/s.

Use the vapor pressure surrogate table (Table J-1) for the above equation.

J.2.3.1.20 Active landfill (emission source No. 20). Each Monday at 0900 hours, an open dump truck containing 19 m³ bulk solids from the filter press (see Section J.2.3.1.5) is emptied at the active landfill. Each Friday at 1000 hours, an open dump truck containing 19 m³ bulk solids from the sand filters (see Section J.2.3.1.12) is emptied at the active landfill. Each Monday at 1000 hours, an open dump truck containing 16 m³ of bulk solids from drums is emptied at the active landfill. On the first Monday of each month at 1400 hours, 59 m³ of fixed waste is disposed of at the landfill. Use the vapor pressure surrogates. Emissions occur from the uncovered waste for 1 week before it is covered.

Active Landfill Loading = 1.94×10^4 g oil/m³ soil, water = 50 percent, weekly depth of waste = 1.11 m, total porosity = 0.5, air porosity = 0.25, MW_{oil} = 147 g/g mol, exposure time = 7 d, total landfill area = 5×10^4 m².

J.3 LONG-TERM TSDF EMISSION CONTROL STRATEGIES

The two example control strategies described in Chapter 5.0, Section 5.2, were applied to Sites 1 and 2 for each emission source. Control

strategy I is based primarily on the use of individual source (add-on) controls. Control strategy II is based on the application of waste treatment to remove organics prior to placement in open area sources. Storage tanks that hold the waste prior to organic removal are covered, and if they fail the vapor pressure cutoff of 1.5 psia, they are vented to a control device. Both strategies use the concept of a volatile organic (VO) cutoff level of 500 ppm and a vapor pressure cutoff of 1.5 psia as described in Chapter 5.0, Section 5.2.

The baseline for the control strategies will include the land disposal restrictions (LDR) as described in Chapter 5.0. For estimates of controlled emissions, LDR includes the incineration of organic liquid and organic sludge wastes instead of landfilling. Aqueous sludges are solidified under LDR prior to landfilling. Certain wastes may also be banned from surface impoundments under LDR; however, treatment impoundments may be exempted and other impoundments may be replaced by large uncovered tanks. Because impoundments may be exempted or replaced by a source with a similar emission potential, this analysis assumes that LDR will not affect emissions from surface impoundments at the two sites described in this appendix.

The wastes handled at Sites 1 and 2 are mixtures of different waste codes and waste forms. Each of these waste form/waste code combinations has different organic concentrations and different physical/chemical properties; consequently, these different combinations may require different types of organic removal processes. For this analysis, weighted average organic removal process efficiencies were derived for each waste stream mixture based on the waste code and form, the associated organic process removal efficiencies, and the quantity of the waste stream. The process removal efficiencies are based on those used in the Source Assessment Model and are given in Appendix D.

In this analysis, the waste stream mixtures are separated into their individual waste streams, the VO content, as measured by the VO test method (see Appendix G), is estimated for the individual stream, and the individual streams are composited into two groups. One group contains those waste streams with a total VO content less than 500 ppm, and the other is composed of waste streams with a total VO content greater than 500 ppm.

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For control strategy I, process units that receive wastes with a V0 content greater than the 500-ppm cutoff are covered. The waste streams with a V0 content less than the 500-ppm cutoff are assumed to be processed through the facility as defined for the baseline case (open-area sources remain uncovered). Storage tanks that receive waste streams that exceed the vapor pressure cutoff of 1.5 psia are controlled at 95 percent, and storage tanks that pass the vapor pressure cutoff are not controlled. The emissions from these three types of waste streams are added for each source to estimate the cumulative effect of control strategy I on emissions. For control strategy II, organic removal processes are applied to the waste stream mixtures with a V0 content greater than the 500-ppm cutoff level. The treated wastes (after organic removal) are combined with the wastes that pass the cutoff and are processed through the facility as defined for the baseline case.

The analysis used to estimate the VO content of individual waste streams is based on what the VO test method is projected to measure (see Appendix G). The approach uses factors derived for steam distillation with 20-percent boilover to adjust for the percent recovery of high, medium, and low volatiles. For example, the appropriate factor (representing the fraction recovered by the method for a given volatility class) is multiplied by the surrogate concentration to predict the concentration that the test method would measure. The test method concentrations are summed for each surrogate to obtain the total VO as measured by the test method. This total is compared to the VO cutoff level of 500 ppm to determine whether control is required. These test method correction factors are used only to determine which waste streams in the mixture require control. The estimates of impacts are based on the surrogates and their actual concentrations in the waste stream mixtures.

J.3.1 Long-Term Control Strategies for Site 1

Table J-11 summarizes the controls applied to each source at Site 1 for the two example control strategies. For control strategy I, waste streams exceeding the VO cutoff (500 ppm) require that open area sources be enclosed and vented to a carbon adsorber. Storage tanks that are covered

		Example cont	trol strategy ^b
	Emission source	I	IIc
1.	Drum storage and transfer bldg. a. Storage tanks b. Drum storage	Vent to carbon adsorption Collection and removal - 95% No controls	Vent to carbon adsorption Collection and removal - 95% Existing enclosure vented to carbon adsorption
2.	Acid/alkali receiving area	Vent tanks to carbon adsorption Collection and removal - 95%	Vent tanks to carbon adsorption Collection and removal - 95%
3.	North equalization basin	Cover and vent to carbon adsorption Collection and removal - 95%	Organic removal HV - 99.98%, MV - 93.13% LV - 15.66% Overhead control - HV - 98.40% MV - 99.96%, LV - 99.99%
4.	South waste receiving area	Vent tanks to carbon adsorption Collection and removal - 95%	Vent tanks to carbon adsorption Collection and removal - 95%
5.	Cyanide pretreatment	Cover and vent to carbon adsorption Collection and removal - 95%	Cover and vent to carbon adsorption Collection and removal - 95%
6.	Chrome reduction	Cover and vent to carbon adsorption Collection and removal - 95%	Cover and vent to carbon adsorption Collection and removal - 95%
7.	Neutralization tank	Cover and vent to carbon adsorption Collection and removal - 95%	Cover and vent to carbon adsorption Collection and removal - 95%
8.	South equalization basin	Cover and vent to carbon adsorption Collection and removal - 95%	Organic removal HV - 99.93%, MV - 85.92% LV - 17.72% Overhead control - HV - 98.40% MV - 99.96%, LV - 99.99%
9.	Aqueous waste clarifier	Cover and vent to carbon adsorption Collection and removal - 95%	No controlsd
10.	Rotary vacuum filters	No controls	No controls
11.	Sludge loading area	No controls	No controls
12.	Receiving tank 8	Cover and vent to carbon adsorption Collection and removal - 95%	Cover and vent to carbon adsorption Collection and removal - 95%

TABLE J-11. DETAILED FACILITY ANALYSIS: TSDF SITE 1 EXAMPLE CONTROL STRATEGIES APPLICATIONS^a

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	Example control strategy ^b	
Emission source'	I	IIc
13. Recovered waste oil storage tanks	Vent to carbon adsorption Collection and removal - 95%	Vent to carbon adsorption Collection and removal - 95%
14. Reusable chlorinated solvent storage tank	Vent to carbon adsorption Collection and removal - 95%	Vent to carbon adsorption Collection and removal - 95%
15. Waste oil storage tank	Vent to carbon adsorption Collection and removal - 95%	Vent to carbon adsorption Collection and removal - 95%

TABLE J-11 (continued)

TSDF = Treatment, storage, and disposal facility.

VO = Volatile organic.

HV = High volatile organic.

MV = Medium volatile organic.

LV = Low volatile organic.

^aThis table presents the control devices and efficiencies required for the management units at Site 1 based on the example control strategies presented in Chapter 5.0, Section 5.2.

^bExample control strategy I applies to wastes containing greater than 500 ppm of VO. It generally entails covers and controls for tanks and impoundments, submerged loading of drums, and covers for dumpsters. Example control strategy II applies to wastes containing greater than 500 ppm VO. It generally entails introducing organic removal processes before treatment tanks, storage or treatment impoundments, and waste fixation processes; covers and controls for storage tanks; enclosure and control of drum storage areas; submerged loading of drums; covers for dumpsters; and inspection and monitoring of equipment leak sources.

^CThe organic removal process efficiencies are weighted according to the control efficiencies associated with each waste form processed at a given management unit. The weighted organic removal efficiencies are based on the thin-film evaporator and the steam stripper efficiencies as shown in Appendix D.

^dThis management unit requires no controls because the previous management unit is controlled using a organic removal device.
are also vented to a carbon adsorber. Sludge that is loaded onto a dumpster (Source 11) is covered to control emissions. As discussed in Section 5.2, equipment leak emissions (e.g., leaks from pumps) will be controlled by the TSDF air standards for fugitive emissions and process vent controls for waste streams containing 10 percent or more organics. For control strategy II, organic removal processes are applied to wastes with VO greater than 500 ppm before the waste enters the North equalization basin (Source 3) and the South equalization basin (Source 8). Because the waste has been pretreated before it enters the clarifier (Source 9), no controls are required for this open source. For control strategy II, inspections, monitoring, and equipment standards are an additional requirement for control of equipment leak emissions for waste streams with organic concentrations of 10,000 ppm or greater.

J.3.2 Long-Term Control Strategies for Site 2

The controls applied to the emission sources at Site 2 for the example strategies are summarized in Table J-12. For control strategy I and wastes exceeding the 500-ppm VO cutoff, open sources are enclosed and all enclosed sources are vented to a carbon adsorber. Sludge loaded into a dumpster (Sources 5 and 12) is covered to reduce emissions. The controls for landfills are those from the LDR, which include incineration of organic liquids and sludges and the solidification of aqueous sludges prior to landfilling. Control strategy II requires removal of organics for wastes exceeding the VO cutoff before placement in surface impoundments or the fixation pit. In addition, removal of organics is required for waste mixture 5 before it enters the impoundment (Source 10) at the Phase 2 treatment system. The tanks and impoundments that follow Source 10 in the treatment train do not require control under control strategy II because the waste has already been treated to remove organics. Equipment leak emissions for both strategies are controlled as described for Site 1. J.3.3 Annual Average Emission Estimates

The estimates of annual average emissions for each site are summarized in Table J-13 for the two example control strategies. Because there are no sources at Site 1 affected by LDR, the emissions for the uncontrolled and LDR cases are the same. At Site 2, the oily waste (waste mixture 4) is incinerated instead of landfilled under LDR and the aqueous sludges are solidified prior to landfilling. The effect of LDR on total emissions at

		Example con	trol strategy ^b
	Emission source	I	IIc
1.	Drum storage and transfer	No controls	Existing structure vented to carbon adsorption Collection and removal - 95%
2.	L1 - tank storage	Vent to carbon adsorption Collection and removal - 95%	Vent to carbon adsorption Collection and removal - 95%
з.	Neutralization tank	Cover and vent to carbon adsorption Collection and removal - 95%	Cover and vent to carbon adsorption Collection and removal - 95%
4.	Surface impoundment - flowthrough	Cover and vent to carbon adsorption Collection and removal - 95%	Organic removal HV – 99.97%, MV – 92.50% LV – 16.75% Overhead control – HV – 98.40% MV – 99.96%, LV – 99.9%
5.	Filter press	No controls	No controls
6.	Aerated surface impoundment	Cover and vent to carbon adsorption Collection and removal - 95%	No controls ^e
7.	Surface impoundment - flowthrough	Cover and vent to carbon adsorption Collection and removal - 95%	No controls ^e
8.	Storage tank	Vent to carbon adsorption Collection and removal - 95%	Cover and vent to carbon adsorption Collection and removal - 95%
9.	Storage tank	Vent to carbon adsorption Collection and removal - 95%	No controls [®]
10.	Surface impoundment - aerated	Cover and vent to carbon adsorption Collection and removal - 95%	Organic removal for waste stream mixture 5, HV - 99.99%, MV - 94.50%, LV - 16.45% Overhead control, HV - 98.40%, MV - 99.96%, LV - 99.99%
11.	Neutralization tank	Cover and vent to carbon adsorption Collection and removal - 95%	No controls ^e
12.	Sand filters	No controls	No controls
13.	Surge tank	Vent to carbon adsorption Collection and removal - 95%	No controls ^e

TABLE J-12. DETAILED FACILITY ANALYSIS: TSDF SITE 2 EXAMPLE CONTROL STRATEGIES APPLICATIONS^a

(continued)

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		Example con	trol strategy ^b
	Emission source urface impoundment aerated urface impoundment aerated urface impoundment aerated ischarge of liquids from 6. surface impoundment losed landfills ixation pits	I	IIc
14.	Surface impoundment - aerated	Cover and vent to carbon adsorption Collection and removal - 95%	No controls ^e
15.	Surface impoundment - aerated	Cover and vent to carbon adsorption Collection and removal - 95%	No controls ^e
16.	Surface impoundment - aerated	Cover and vent to carbon adsorption Collection and removal - 95%	No controis ^e
17.	Discharge of liquids from 16. surface impoundment	No controls	No controls
18.	Closed landfills	No controls	No controls
19.	Fixation pits	No controls	Organic removał HV – 99.98%, MV – 96.55% LV – 76.63% Overhead control – HV – 98.56% MV – 98.99%, LV – 99.00%
2Ø.	Active landfilld	No controls	No controls

TSDF = Treatment, storage, and disposal facility.

VO = Volatile organic.

HV = High volatile organic.

MV = Medium volatile organic.

LV = Low volatile organic.

^aThis table presents the control devices and efficiencies required for the management units at Site 2 based on the example control strategies presented in Chapter 5.0, Section 5.2.

^bExample control strategy I applies to waste containing greater than 500 ppm of VO. It generally entails covers and controls for tanks and impoundments, submerged loading of drums, and covers for dumpsters.

Example control strategy II applies to wastes containing greater than 500 ppm VO. It generally entails introducing organic removal processes before treatment tanks, storage or treatment impoundments, and waste fixation processes; covers and controls for storage tanks; enclosure and control of drum storage areas; submerged loading of drums; covers for dumpsters; and inspection and monitoring of equipment leak sources.

^CThe organic removal process efficiencies are weighted according to the control efficiencies associated with each waste form processed at a given management unit. The weighted organic removal efficiencies are based on the rotary kiln incinerators, thin-film evaporator and steam stripper efficiencies as shown in Appendix D.

^dLand disposal restrictions have been applied concerning the wastes processed at the landfill. Organic liquids originally destined for landfilling are shipped offsite in response to the land disposal restrictions. No controls are applied to the landfill itself

^eThis management unit requires no controls because a previous management unit is controlled using a organic removal device.

	Organic emissions (Mg/yr)					
Control case	Site 1	Site 2				
Uncontrolled	337	356				
Baseline (LDR) ^b	337	352				
Control strategy I ^C	11	е				
Control strategy II ^d	16	е				

TABLE J-13. DETAILED FACILITY ANALYSIS: ESTIMATES OF ANNUAL AVERAGE ORGANIC EMISSIONS FOR TSDF SITES 1 AND 2^a

TSDF = Treatment, storage, and disposal facility. LDR = Land disposal restrictions.

^aThis table presents the estimates of annual average emissions for the two sites for the uncontrolled case, baseline case, and the two example control strategies described in Chapter 5.0.

^bThe baseline will include regulations anticipated in the LDR and any emission reductions associated with them. LDR is projected to affect only the active landfill at Site 2.

^CControl strategy I is based primarily on enclosure and venting to a control device.

dControl strategy II is based primarily on organic removal treatment and venting enclosed sources to a control device.

^eThe results from Site 1 are used to estimate maximum lifetime risk in Chapter 6.0. Site 1 has a higher ambient concentration, and, in turn, higher risk than Site 2 for control strategies 1 and 2. Site 2 is small because the emission reduction occurs only for the active landfill, which contributes a very small percentage to the uncontrolled emissions.

For control strategy I, open area sources receiving wastes with over 500 ppm VO are covered. Those open sources that are operated at a nearly constant liquid level are assumed to contribute breathing emissions after covering; however, loading emissions are assumed to be negligible because the flow into these covered sources equals the flow out of the source. For covered sources that are alternately loaded and then unloaded, working (loading) losses are included in addition to breathing emissions. Storage tanks that fail the vapor pressure cutoff are controlled, and storage tanks that pass the vapor pressure cutoff are not controlled. Emission estimates are also included for those waste streams that pass the VO cutoff based on processing in uncontrolled sources. The approach for control strategy II is based on sending wastes that require pretreatment (VO greater than 500 ppm) to a storage tank prior to removing organics. Storage tanks are controlled based on vapor pressure as described for control strategy I. Other wastes (VO less than 500 ppm) are processed through the regular treatment process. After removal of organics, the treated waste is combined with the wastes that do not require pretreatment and the composite mixture is processed through the wastewater treatment system. For all cases in sequential processing steps, the concentration in the waste as it enters a subsequent process unit is reduced by the amount that is lost by air emissions (or organic removal processing) in a prior process unit. Emissions from the pretreatment device are based on the concentration and flow rate of the stream to be treated, the organic removal process efficiency (Table J-11), and the overhead control efficiency (Table J-11).

Control strategy I results in an emission reduction from the baseline of 97 percent for Site 1. Control strategy II provides an emission reduction of 95 percent for Site 1. Site 1 resulted in a higher ambient concentration, and, in turn, higher risk than Site 2. Its risks are presented in Chapter 6.0. The emission estimates for control strategy I are lower than those for control strategy II primarily for two reasons. The emissions for covering the sources (strategy I) are based on breathing emissions only for most sources that were previously open (no loading emissions) because they are assumed to be operated at a nearly constant

liquid level. Breathing emissions are very low compared to loading emissions. For organic removal (strategy II), the uncovered aerated sources remain uncovered. However, some moderate and low volatiles remain in the treated waste stream after organic removal and are emitted in the uncovered aerated units. Consequently, covering (strategy I) controls all of the compounds whereas organic removal (strategy II) is most effective for control of the more volatile compounds and is less effective than covering for the less volatile compounds. A significant difference between the two control strategies is the organic content of the wastewater discharged from the facility. Under control strategy I (covers), the organics are suppressed and remain for the most part in the wastewater; consequently, the water discharge under this strategy contains a high level of organics. Under control strategy II, significant quantities of organics are removed during pretreatment and the concentration of organics in the discharge is much lower than that from control strategy I.

The annual average emission estimates for each source will be used in the dispersion modeling analysis discussed in Appendix E. The dispersion modeling uses the Industrial Source Complex-Long Term (ISCLT) model, the site-specific layout and description of emission sources, and site-specific meteorological data to estimate maximum annual ambient air concentrations at receptors placed at the facility's property line. The emission estimates and dispersion modeling results are used with the composite unit risk factor for organics (Appendix E) to estimate the maximum lifetime risk from organic emissions for each example control strategy and for each site.

J.4 SHORT-TERM CONTROLS

After the modeling of uncontrolled short-term emissions, the need to assess short-term controls will be determined. If the long-term control strategies do not provide adequate control of peak emissions, additional control strategies will be investigated.

J.5 DISPERSION MODELING FOR CHRONIC HEALTH EFFECTS ASSESSMENT

One portion of the health effects assessment is concerned with quantifying health effects associated with long-term exposure to potentially hazardous substances emitted from TSDF. Included in this portion of the assessment are effects due to chronic exposure to both noncancer toxicants and carcinogens. In order to conduct this assessment, estimates of ambient concentrations of these substances in the vicinity of TSDF are required. For this assessment, the ambient concentration estimates have been obtained by estimating the magnitude of air emissions occurring at TSDF using emission models and by applying an atmospheric dispersion model to simulate the transport and dispersion of the emitted substances downwind of a facility. This section describes the application of the dispersion model to obtain the estimates of ambient concentration.

Atmospheric dispersion models have traditionally been used to relate air emissions of pollutants occurring at a source to ambient concentrations at downwind locations. These models are made specific to the application under consideration by including in the application the following factors: the rate of emission at each source, the physical configuration of each source, the locations of sources with respect to the areas at which ambient concentrations are to be estimated, and the meteorology affecting the transport and dispersion of the air emissions. For the modeling analysis described here, this type of an application was conducted to estimate ambient concentrations in the vicinity of two TSDF. The selection and characterization of the two TSDF were described previously, and the data presented there were used to develop the atmospheric dispersion model inputs described in this section. In all model applications, primary emphasis was placed on determining the highest ambient concentrations at the facility fencelines or beyond in order to quantify the greatest human exposure. This type of information can be used, for example, to determine the maximum exposed individual for a cancer risk assessment (i.e., maximum individual risk or maximum lifetime risk). Analyses designed to measure aggregate population risk (e.g., the number of annual incidences) are described in Appendix E.

Atmospheric dispersion models are routinely applied to relate ambient concentrations of a specific pollutant to source emission rates of that pollutant. For this analysis, however, a somewhat different approach was used in order to provide an efficient procedure for estimating ambient concentrations for a number of hazardous pollutants. In the approach used here, "normalized" ambient concentrations are computed as the ratio of

downwind ambient concentration to the source emission rate. The normalized ambient concentrations can then be used to estimate ambient concentrations of any specific pollutant by multiplying the normalized value by the "true" source emission rate of the pollutant. Because the atmospheric dispersion model need only be applied once, this approach is particularly suited to estimating ambient concentrations for a large number of substances, as well as for evaluating several control scenarios in which the emission rates of individual sources are altered.

The discussion below is divided into three parts. The first briefly describes the particular atmospheric dispersion model used in this analysis. The second part describes in general terms the use of normalized concentrations in estimating ambient concentrations of specific pollutants. The third and final portion of this section describes the applications of the atmospheric dispersion model to the two TSDF modeled in this study. As discussed in Appendix E, the results of this dispersion modeling are used to estimate ambient concentrations of both individual toxicants and total volatile organic compounds. Because only normalized concentrations were generated with the atmospheric dispersion model, however, the discussions below are not pollutant-specific. A description of the specific pollutants E. J.5.1 Description of the Atmospheric Dispersion Model

The atmospheric dispersion model used in this study was selected on the basis of its applicability to the specific situations being modeled and the outputs required for the health effects assessment. TSDF are characterized by a wide variety of source types (e.g., closed roof storage tanks, surface impoundments, open tanks, building fugitives, vents, stacks, and landfills). Sources such as these are represented in dispersion modeling analyses as either point, area, or volume sources. Thus, the model selected for this assessment must have the capability to consider all three source types. Another factor affecting the model selection is the consideration of the averaging times required for estimating ambient concentrations (i.e., short-term averages such as 1 hour or 3 hours versus long-term

averages such as annual or multiyear). Because only long-term averages are needed for the chronic portion of the health effects assessment, a computationally efficient model type capable of producing such estimates was selected.

The particular model selected for this analysis is the ISCLT model.^{5,6} The ISCLT 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 resulting from air emissions from these source types in a computationally efficient manner. ISCLT is recognized by the <u>Guideline on Air Quality</u> <u>Models</u> as a preferred model for dealing with complicated sources (i.e., facilities with point, area, and volume sources) when estimating long-term concentrations (i.e., monthly or longer).⁷ The current UNAMAP 6 version of ISCLT as implemented on EPA's National Computing Center (NCC) UNIVAC 1100 computer system was used in all model applications described in this section.⁸

As described in the <u>Guideline on Air Quality Models</u>, the ISCLT is appropriate for modeling industrial source complexes in either rural or urban areas located in flat or rolling terrain. With this model, long-term ambient concentrations can be estimated for transport distances up to 50 km. The ISCLT incorporates separate point, area, and volume source computational algorithms for calculating ambient concentrations at userspecified locations (i.e., receptors). The locations of the receptors relative to the source locations are determined through a user-specified Cartesian coordinate reference system.

ISCLT source inputs vary according to source type. For point sources, the inputs include emission rate, physical stack height, stack inner diameter, stack gas exit velocity, and stack gas exit temperature. If the stack is located adjacent to a building and aerodynamic wake effects are to be considered, the building dimensions are also required as inputs. Inputs for the other two types of sources include emission rate, horizontal dimensions of the source, and the effective height of release. Individual area sources are required to have the same north-south and east-west dimensions (i.e., they must be square), but multiple square area sources of different size can be used to approximate the geometry of a source of another shape. Horizontal dimensions of volume sources can be determined from the physical dimensions of the source using procedures contained in the ISCLT User's Manual.⁹

The ISCLT is a sector-averaged model that uses statistical summaries of meteorological data to calculate long-term, ground-level ambient concentrations. The principal meteorological inputs to the ISCLT are stability array (STAR) summaries that consist of a tabulation of the joint frequency of occurrence of windspeed categories and wind-direction sectors, classified according to Pasquill atmospheric stability categories. STAR summaries are routinely generated from meteorological data collected at major U.S. meteorological monitoring sites that are available from the National Climatic Center in Asheville, NC. As recommended in the <u>Guideline on Air</u> <u>Quality Models</u>, a 5-year period of record was used in generating the STAR summaries used in the model applications described below. Other meteorological data requirements include average maximum and minimum mixing heights and ambient air temperatures. Recommended procedures for developing these inputs are contained in the ISCLT User's Manual.

The discussion above is intended to provide a brief overview of the ISCLT model and some of its features. It should be noted that the model contains a number of features not relevant to the applications discussed here, and thus the model description is not comprehensive in nature. For a more complete discussion of the model, the reader is referred to References 5 and 6.

J.5.2 Normalized Concentrations

As described above, the ISCLT model computes long-term ambient concentrations at user-specified receptor points that occur as a result of air emissions from multiple sources. These computations are done on a sourceby-source basis such that the ambient concentration from each source at each receptor is computed. Total ambient concentrations at a particular receptor are obtained by summing the contributions from each of the sources. With Gaussian plume algorithms such as those included in the ISCLT, the source contributions at each receptor are directly proportional to the source emission rate. As a result, ambient concentrations corresponding to any number of desired source emission rates can be obtained by applying the atmospheric dispersion model once, and scaling the ambient concentrations by the ratio of the desired emission rate to that used in the dispersion model application. This is the approach that has been used for this analysis, and it is described below.

Normalized ambient concentrations for each source-receptor combination were computed such that they would correspond to a unit emission rate of 1 g/s for each source in the facility. The total ambient concentration at a receptor is then computed as the sum of the contributions from each source, where the latter are computed as the product of the normalized concentration and the desired emission rate. Mathematically, this can be expressed as follows:

$$X_{i} = \sum_{j=1}^{J} q_{i} X_{ij} , \qquad (J-1)$$

 X_i = total ambient concentration at receptor i, $\mu g/m^3$

 $q_i = emission rate for source, g/s$

 $x_{ij} = normalized$ source contribution from source j to receptor i, $\mu g/m^3$

J = total number of sources at the TSDF.

Thus, the principal output of the dispersion modeling applications is a set of normalized source contributions, i.e., x_{ij} in Equation (J-1) for each facility modeled.

In the formulation presented in Equation (J-1) above, both the individual normalized source contributions and total ambient concentrations represent multiyear averages because a 5-year period of record was used in developing the statistical STAR summaries. The emission rates in Equation (J-1) are also long-term estimates (e.g., annual average values), although they are expressed on a gram-per-second basis. All ISCLT outputs generated for this analysis were structured such that the total emission rate for each source could be used in Equation (J-1). In a few instances, a TSDF source group was represented by a small number of individual sources in the

ISCLT modeling analyses. When this situation involved point or volume sources, the total source group emission rate was apportioned equally among the individual ISCLT sources. This was performed in the modeling analyses by setting the input ISCLT source emission rate equal to the reciprocal of the number of sources in the group. In an analogous manner, the input ISCLT emission rates for all area sources were set to the reciprocal of the total area of the source because area source inputs for ISCLT are expressed on an emission density basis (i.e., grams per square meter per second). Thus, all normalized source contributions output for developed in this analysis are on a gram per second basis for the entire source group, regardless of the type of source or the number of individual sources used to represent the group.

J.5.3 Dispersion Model Application

This section describes the ISCLT model applications conducted in order to estimate the normalized concentrations for use in Equation (J-1) for each of the two TSDF described earlier. Described below are the ISCLT source inputs, the meteorological data used in the modeling analyses, the receptor networks, and other model options.

Tables J-14 and J-15 list the source inputs used in the modeling application for each of the two TSDF. The tables list an ISCLT source group number, an ISCLT source reference number, the emission source number assigned earlier in this appendix, a brief source description, and the source and effluent characteristics used in the ISCLT modeling analyses. Normalized concentrations were developed only for each ISCLT source group. In most cases, each group corresponds to a single ISCLT source. In a few instances, however, a source group is represented by more than one ISCLT source in order to better approximate the geometry of the source or to combine sources when their emissions are equally apportionable among the individual sources. In these cases, the normalized concentrations for the source group are equal to the sum of the contributions from the individual ISCLT sources making up the group. With respect to the source characterizations, sources with emissions released at ground level from open areas are usually modeled as area sources, stacks as point sources, and closed and open storage tanks as volume sources. In the latter case, initial

		Source iden	tification	-					Vectical	
ISCLT group	ISCLT source	Emission source		Source	Emission	Source coo	ordinates ^b	Source height,	dispersion coefficient,	Horizontal dimension, ^c
number	number	number	Source description	type	rateª	x,M	y,m	m	m	M
1	1	1	Aqueous Drum Unioad	Area	0.00148	70.0	165.0	7.0	0.0	15.Ø
1	2	1	Aqueous Drum Unload	Area	0.00148	85.Ø	165.0	7.0	0.0	15.0
1	3	1	Aqueous Drum Unload	Area	0.00148	100.0	185.0	7.0	0.0	15.0
2	4	1	Waste Oil Unload	Area	0.00444	74.0	144.0	7.0	0.0	15.0
3	6	1	Tank Truck Loading	Volume	1.0	91.Ø	183.0	3.7	1.7	0.9
4	6	2	Acid/Alkali Rovg Area	Vo (ume	1.0	177.0	217.0	3.0	1.4	0.9
6	7	2	Acid/Alkali Rovg Area	Volume	1.0	187.0	217.0	3.0	1.4	0.9
8	8	2	Acid/Alkali Rcvg Area	Volume	1.0	167.Ø	217.0	3.0	1.4	Ø.9
7	9	2	Acid/Alkali Rovg Area	Volume	1.0	167.Ø	227.0	3.0	1.4	0.9
8	10	2	Acid/Alkali Rcvg Area	Volume	1.0	177.Ø	227.0	3.0	1.4	Ø.9
9	11	2	Acid/Alkali Rovg Area	Volume	1.0	187.0	227.0	3,0	1.4	0.9
10	12	З	North Equalization Basin	Area	0.0121	206.0	214.0	0.0	0.0	9.1
11	13	4	South Waste Rovg Area	Volume	1.0	277.0	202.0	3.0	1.4	Ø.9
12	14	4	South Waste Rovg Area	Volume	1.0	277.0	217.0	3.0	1.4	0.9
13	15	4	South Waste Rovg Area	Volume	1.0	287.0	217.Ø	3.0	1.4	Ø.9
14	16	4	South Waste Rovg Area	Volume	1.0	277.0	232.0	3.0	1.4	0.9
15	17	5	Cyanide Pretreatment	Volume	1.0	258.Ø	203.0	3.0	1.4	1.3
16	18	6	Chrome Reduction	Volume	1.0	258.0	233.0	3.0	1.4	1.3
17	19	7	Neutralization Tank	Volume	1.0	259.0	220.0	Б.Ø	2.3	2.0
18	20	8	South Equalization Basin	Area	0.00913	231.0	215.0	0.0	0.0	7.4
18	21	8	South Equalization Basin	Area	0,00913	238.0	219.0	0.0	0.0	7.4

TABLE J-14. SOURCE CHARACTERIZATION FOR SITE 1

(continued)

		Source iden	tification						Vertical	-
ISCLT group number	ISCLT source number	Emission source number	Source description	Source type	Emission rate ^a	<u>Source co</u> x,m	ordinates ^b y,m	Source height, m	dispersion coefficient, m	Horizontal dimension, ^c m
19	22	9	Aqueous Waste Clarifier	Area	0.00913	230.0	194.0	0.0	0.0	7.4
19	23	9	Aqueous Waste Clarifier	Area	0.00913	230.0	198.0	0.0	0.0	7.4
20	24	10	Rotary Vacuum Filters	Volume	1.0	235.0	173.0	6.0	2.8	2.8
21	25	11	Sludge Loading Area	Volume	1.0	235.0	148.0	6.0	2.8	2.8
22	26	12	Rovg Tank B	Volume	1.0	167.0	167.0	2.5	1.2	Ø.7
23	27	12	Rovg Tank 8	Volume	1.0	177.0	167.0	2.5	1.2	0.7
24	28	12	Rovg Tank 8	Volume	1.0	177.0	177.0	2.5	1.2	Ø.7
25	29	12	Rcvg Tank 8	Volume	1.0	167.Ø	177.0	2.5	1.2	0.7
26	30	13	Rcvg Waste Oil Stor. Tank	Volume	1.0	180.0	160.0	1.8	0.8	0.6
27	31	14	Reusable Chl. Solv. Storage	Volume	1.0	165.Ø	150.0	2.0	0.9	Ø.5
28	32	16	Pretreatment Device	Point	1.0	125.0	175.0	9.2	NAd	NA

TABLE J-14 (continued)

^ag/s for point and volume sources; g/m²-s for area sources.

^bRelative coordinate system.

^cHorizontal dispersion coefficient for volume sources; horizontal dimension for area sources.

dNot applicable to point sources; for ISCLT source number 32, the effluent temperature is 298 K, the stack exit velocity 0.4 m/s, and the stack diameter 0.1 m.

		Source iden	tification						Vectical	
ISCLT group	ISCLT source	Emission source		Source	Emission	Source co	ordinates ^b	Source height,	dispersion coefficient,	Horizontal dimension, ^c
number	number	number	Source description	type	ratea	×,m	y,m	m	m	m
1	1	1	Drum Transfer and Storage	Volume	1.0	1160.0	76Ø.Ø	6.1	2.8	18.4
2	2	2	Tank Storage L1	Volume	1.0	720.0	770.0	10.0	4.7	3.0
з	3	з	Neutralization Tank LR	Volume	1.0	770.0	765.Ø	5.0	2.3	1.4
4	4	4	Surface Impoundment L2	Агеа	0.00826	810.0	765.Ø	0.0	Ø.Ø	11.0
Б	5	Б	Filter Press	Volume	1.0	840.0	765.Ø	10.0	4.7	2.3
6	6	6	Aerated Impoundment L3	Агеа	0.00444	85Ø.Ø	765.Ø	Ø.Ø	0.0	15.0
7	7	7	Surface Impoundment L4	Агеа	0.00444	900.0	765.0	0.0	Ø.Ø	15.0
8	8	8	Storage Tank L5	Volume	1.0	180.0	400.0	6.0	2.8	3.2
9	9	9	Storage Tank L8	Volume	1.0	180.0	350.0	6.0	2.8	3.2
10	10	10	Surface Impoundment L7	Volume	1.0	180.0	310.0	6.0	2.8	3.2
11	11	11	Neutralization Tank LB	Volume	1.0	180.0	270.0	6.0	2.8	3.2
12	12	12	Sand Filters	Volume	1.0	180.0	220.0	10.0	4.7	2.3
13	13	13	Surge Tank L9	Volume	1.0	180.0	210.0	6.0	2.8	3.2
14	14	14	Surface Impoundment L10	Volume	1.0	180.0	180.0	12.0	5.8	13.7
15	15	15	Surface Impoundment L11	Volume	1.0	220.0	180.0	6.0	2.8	3.2
16	16	16	Surface Impoundment L12	Volume	1.Ø	220.0	210.0	6.0	2.8	3.2
17	17	18	Closed Landfill SCFM1	Area	f	6Ø5.Ø	218.0	Ø.Ø	0.0	58.3
17	18	18	Closed Landfill SCFM1	Area	f	663.Ø	218.0	0.0	0.0	58.3
17	19	18	Closed Landfill SCFM1	Агеа	f	605.0	160.0	0.0	0.0	58.3
17	20	18	Closed Landfill SCFM1	Агеа	f	663.Ø	160.0	0.0	0.0	58.3
18	21	18	Closed Landfill SCFM2	Агеа	f	475.0	223.0	0.0	0.0	62.5

TABLE J-15. SOURCE CHARACTERIZATION FOR SITE 2

(continued)

		Source iden	tification	_						
ISCLT group	ISCLT source	Emission source		Source	Emission	Source co	ordinates ^b	Source height,	dispersion coefficient,	Horizontal dimension, ^c
number	number	number	Source description	type	rate ^a	x,m	y,m	m	m	m
18	22	18	Closed Landfill SCFM2	Area	, f	538,Ø	223.Ø	0.0	Ø.Ø	62.5
18	23	18	Closed Landfill SCFM2	Area	f	475.0	160.0	Ø.Ø	Ø.Ø	62.5
18	24	18	Closed Landfill SCFM2	Area	f	538.0	160.0	0.0	0.0	62.5
19	25	18	Closed Landfill SCFM3	Area	f	260.0	161.0	0.0	0.0	56.Ø
19	26	18	Closed Landfill SCFM3	Area	f	306.0	161.Ø	0.0	0.0	56.0
19	27	18	Closed Landfill SCFM3	Area	f	362.Ø	161.0	0.0	0.0	56.0
19	28	18	Closed Landfill SCFM3	Агеа	f	418.0	161.0	0.0	0.0	56.Ø
19	29	18	Closed Landfill SCFM3	Area	f	250.0	150.0	0.0	0.0	66.0
19	30	18	Closed Landfill SCFM3	Area	f	306.0	150.0	Ø.Ø	0.0	56.0
19	31	18	Closed Landfill SCFM3	Area	f	362.0	150.0	0.0	0.0	58.Ø
19	32	18	Closed Landfill SCFM3	Area	f	418.0	150.0	0.0	0.0	56.0
20	33	18	Closed Landfill SCFM4	Агеа	f	1500.0	1000.0	0.0	0.0	100.5
20	34	18	Closed Landfill SCFM4	Area	f	1602.0	1000.0	0.0	0.0	100.5
20	35	18	Closed Landfill SCFM4	Агеа	f	1500.0	900.0	0.0	0.0	100.5
20	36	18	Closed Landfill SCFM4	Area	f	1602.0	900.0	0.0	0.0	100.5
21	37	19	Fixation Pit	Point	Ø.5	1140.0	660.0	17,1	NAd	NAd
21	38	19	Fixation Pit	Point	Ø.5	1140.0	885.Ø	27.1	NAd	NAd
22	39	20	Active Landfill SCFM5	Агев	0.000020	1255.0	652.0	0.0	0.0	7.Ø
22	40	20	Active Landfill SCFM5	Area	0.000020	1367.0	852.0	0.0	0.0	112.0
22	41	20	Active Landfill SCFM5	Area	0.000020	1255.0	540.0	0.0	0.0	112.0
22	42	20	Active Landfill SCFM5	Area	0,000020	1367.0	540.0	0.0	0.0	112.0
23	43	21	Pretreatment Device	Point	1.0	660.0	780.0	9.2	NA®	NA®

TABLE J-15 (continued)

(continued)

TABLE J-15 (continued)

 $^{a}g/s$ for point and volume sources; $g/m^{2}-s$ for area sources.

^bRelative coordinate system.

CHorizontal dispersion coefficient for volume sources; horizontal dimension for area sources.

dNot applicable to point sources; for ISCLT source numbers 37 and 38, the effluent temperature equals the ambient temperature, the stack exit velocity is 18.8 m/s, and the stack diameter is 1.3 m.

^eNot applicable to point sources; for ISCLT source number 43, the effluent temperature equals the ambient temperature, the stack exit velocity is 0.4 m/s, and the stack diameter is 0.1 m.

 $^{
m f}$ Emissions from closed landfills are not included because of a lack of information on waste concentrations within the source.

horizontal and vertical dispersion coefficients for volume sources were derived from the physical dimensions of the source according to the procedures recommended in the ISCLT User's Manual.

Meteorological data were chosen to reflect the geographical locations of the TSDF on which the source configurations were based. STAR summaries for both facilities were derived from hourly surface data using the following 5-year periods of record: 1970 through 1974 for Site 1, and 1973 through 1977 for Site 2. In both cases, the TSDF were identified as being located in an urban environment, so the ISCLT urban dispersion coefficients were used in all model simulations. Ambient temperatures for each locale were obtained from Local Climatological Data summaries, and mixing heights from Holzworth.^{10,11} Procedures contained in the ISCLT User's Manual were employed to estimate the ISCLT input values for ambient temperature and mixing height.

The receptor networks used in conjunction with the ISCLT modeling analyses are shown in Figures J-5 and J-6. As noted in the introductory portion of this section, primary emphasis was placed on detecting the highest ambient concentrations at, or outside of, the fenceline of the facility. Because most sources are characterized by emission releases at relatively low heights, the highest ambient concentrations tend to occur nearest the sources. Most of the receptors are, therefore, located at the TSDF fencelines. The receptor networks shown in Figures J-5 and J-6 were developed after performing several sensitivity analyses to identify the location of each source's maximum impact and the likely locations of the greatest aggregate facility impacts.

In addition to source, meteorological, and receptor data, the ISCLT contains a number of options that affect the dispersion model calculations. In general, these options were chosen to be consistent with the regulatory recommendations contained in the <u>Guideline on Air Quality Models</u>. Table J-16 lists several of these, along with other model options that were used to generate the normalized concentrations.

J.5.4 Estimation of Average Annual Ambient Concentration

This appendix provides explanations on (1) how TSDF organic emissions were estimated, and (2) how the dispersion of these emissions was modeled. A detailed discussion on the estimation of maximum lifetime risk is provided in Appendix E. To estimate risk, the ambient concentration of the



Figure J-5. Receptor network for Site 1.



Figure J-6. Receptor network for Site 2.

Urban dispersion mode 3 used.

Terrain effects not included (i.e., no elevated receptors).

Wind system reference height set to 10 m.

ISCLT default values used for vertical potential temperature gradients and for wind profile exponents.

Stack-tip downwash and buoyancy-induced dispersion used for point sources unaffected by building wake effects.

Final plume rise used.

Decay coefficient set to zero.

Correction angle for grid system versus wind direction data is 45 degrees for facility one, and zero for Site 2.

Multiyear concentrations computed using 5-year STAR data.

TSDF organic emissions at the point of human exposure must be known. This is accomplished by multiplying the TSDF emission estimate for each emission source by its corresponding dispersion factor for each receptor. The sum of the products of TSDF emission sources results in a maximum ambient concentration for each receptor expressed in μ g/m³. The receptor with the maximum ambient concentration is used in combination with health effects data to estimate maximum lifetime risk.

J.6 DISPERSION MODELING FOR ACUTE HEALTH EFFECTS ASSESSMENT

The preceding section described the modeling approach used to estimate long-term ambient concentrations for the assessment of both cancer and chronic noncancer health effects. Another aspect of the health effects assessment is the potential for adverse effects that could result from short-term exposures to air emissions from TSDF. Thus, for this assessment, estimates of ambient concentrations for short averaging periods are needed (i.e., averaging times of 24 h and less). The approach used to produce this information consists of integrating short-term TSDF emission models with a short-term air quality dispersion model. The TSDF emission sources within a TSDF, and the air quality dispersion model provides estimates of ambient concentrations of the emitted substances over shortterm periods. The purpose of this section is to describe the modeling approach and the manner in which it was used to generate the ambient concentration estimates needed for the acute health effects assessment.

The short-term modeling analysis described here was conducted in a manner analogous to the long-term approach described in the preceding section. The integrated emission and dispersion models were applied to the two TSDF described earlier in this appendix. As with the application described in the preceding section, this analysis was structured to estimate the highest ambient concentrations of potentially hazardous substances in the vicinity of the facilities in order to assess the potential for the greatest human exposure. The hazardous substances consist of a number of waste constituents that pose a potential health hazard if their ambient concentrations are sufficiently high. Appendix E describes the rationale for selecting the constituents, and Section J.2 of

this appendix lists the specific ones included in the modeling analyses described here. For each constituent, ambient concentrations were estimated for the following short-term averaging periods: 15 min, 1 h, 3 h, 8 h, and 24 h. For the health effects assessments, the concentration estimates obtained from these modeling applications are compared to available health data corresponding to these averaging times.

All of the modeling analyses conducted for the acute health effects assessment were performed using estimated uncontrolled emissions. As such, the potential effects of control strategies in lowering short-term levels were not evaluated. However, some of the results obtained from the shortterm analysis were used to indicate whether control strategy evaluation should be carried out for some constituents to assess their effectiveness in mitigating chronic, noncancer health effects. As is described below, the short-term dispersion model is also capable of producing long-term average concentrations if applied for a sufficiently lengthy period of record. This was done in order to identify those constituents that posed a potential problem with respect to chronic health impacts. Any constituent so identified became a candidate for control strategy evaluation. All subsequent control strategy analyses that were performed were done with the long-term models because they are less costly and require less processing time than do the short-term models.

The remaining portion of this section is divided into two parts. The first describes the modeling approach in general terms, with primary emphasis placed on describing the manner in which the emission models were integrated with the short-term dispersion model. This discussion is followed by a description of the application of that approach to the two TSDF and a summary of the results obtained from that application. The results of the acute health effects assessment itself are described in Appendix E.

J.6.1 <u>Short-Term Modeling</u> Approach

The estimation of short-term ambient concentrations of potentially hazardous substances in the vicinity of TSDF is complicated by several factors. First, a large number of waste constituents must be evaluated, making the analysis relatively resource-intensive. Second, short-term

emission rates of potentially hazardous substances from many of the sources within TSDF are affected by meteorological conditions. In many cases, the meteorological conditions associated with the greatest emission rates are the same conditions that give rise to the greatest atmospheric dispersion (e.g., high ambient temperatures, which are often associated with atmospheric instability, and high windspeeds). Thus, reliable estimates of short-term, maximum ambient concentrations cannot be obtained by selecting source emission rates and meteorologically induced dispersion conditions independently. Finally, the emission rate of a specific substance depends on the concentration of the substance in the waste being processed at the facility. Not only do the concentrations of individual substances in the wastes processed at TSDF vary substantially, but they can also vary significantly from source to source within a TSDF because of the various processing steps used in the treatment of that waste.

Because of the complexities cited above, a specialized modeling procedure was developed to produce the desired ambient concentration estimates. With this approach, mathematical short-term emission models are integrated with a short-term atmospheric dispersion model. The formulation of the emission models that have been developed for the various TSDF sources is discussed in Section J.2 and is summarized here. The short-term emission models provide estimates of hourly emission rates of individual waste constituents using information on the chemical and physical properties of the substance, the source operating practices, the concentration of the substance in the waste, and the meteorological conditions affecting emission rates (e.g., windspeed and temperature). In these models, the physical and chemical properties of a substance are represented by a surrogate chemical with similar properties. The models are structured such that contaminant concentrations leaving a particular treatment step can be estimated, and input to a second emission model used for the treatment step to which the waste is next transferred. The emission models are then linked together to generate estimates of hourly emission rates for all sources individually within a TSDF, and these estimates reflect variations in meteorological conditions, waste concentrations, and the operating practices of the facility.

The emission models discussed above are used to estimate hourly emission rates for each source within a TSDF for use with an atmospheric dispersion model. The dispersion model selected for this application is the Industrial Source Complex Short-term (ISCST) model.¹²,¹³ The ISCST is a Gaussian plume model that is applicable to multiple point, area, and volume sources. As noted in <u>The Guideline on Air Quality Models</u>, ISCST is a preferred model for dealing with complex sources (i.e., facilities with point, area, and volume sources). With this model, industrial surce complexes located in either urban or rural areas with flat or rolling terrain can be modeled. As with the ISCLT model described in the preceding section, ambient concentrations can be estimated for transport distances up to about 50 km. All of the ISCST model applications for the analysis described in this section were performed with the UNAMAP 6 version of ISCST as implemented on EPA's National Computing Center (NCC) UNIVAC 1100 computer system.¹⁴

The ISCST source and receptor inputs are virtually identical to those of the ISCLT, and thus no further discussion is included here. The reader is referred to Section J.5.1 for a brief overview of these inputs, or to the ISCST User's Manual for a more comprehensive description. A major difference between inputs to the ISCLT and ISCST occurs in the form and structure of the meteorological data inputs. With ISCST, these inputs include hourly estimates of wind direction, windspeed, ambient air temperature, Pasquill stability category, and mixing height. These data can be developed by the user, or can be generated from meteorological data collected at various National Weather Service (NWS) monitoring sites located around the country using a preprocessor program described in the User's Manual for Single Source (CRSTER) model. 15 Use of the hourly meteorological data with the dispersion model algorithms contained in ISCST enables the model to calculate 1-h average concentrations at various receptors positioned around the facility being modeled. The model can be run for any number of hours, ranging from one to a complete 366-d year. Concentrations for averaging times longer than 1 h can be calculated directly from the hourly values. For example, if the ISCST is used with a

full year of sequential, hourly meteorological data, annual average concentrations can be computed at each receptor included in the ISCST simulation.

The TSDF emission models and the atmospheric dispersion models are integrated by conducting an annual simulation of the emissions released to the atmosphere and their subsequent transport and dispersion downwind. In this simulation, the emission models are used to calculate the hourly emission rates for each hour of the year, and the dispersion model is used to calculate the resultant ambient concentrations for those same hourly periods. These calculations are performed for each waste constituent included in the modeling application. (In order to minimize computational expenses, the atmospheric dispersion model is run one time with normalized emission rates [see Section J.5.2] to generate all hourly contributions from each source to each receptor. Ambient concentrations of specific constituents are then calculated by merging the emission model estimates with the ISCST output.) The ambient concentrations for the other averaging times of interest are computed directly from the hourly average estimates. For all averaging times longer than 1 h, the concentrations are computed as block averages for successive time periods. For example, the 3-h averages in a single day would correspond to the following time periods: 12-3, 3-6, 6-9, etc. The 15-min average concentrations are estimated from the hourly values using an empirical scheme developed by Briggs that relates concentrations for different averaging times to atmospheric stability and emission release height.¹⁶ Finally, the EPA-recommended approach for treating calm wind situations is used in the computation of the concentrations for each of the averaging times. 17 WIth this method, hours with calm winds are treated as missing data, and the longer-term averages are adjusted according to the number of such periods occurring during the averaging period.

J.6.2 Short-term Model Application

The short-term modeling approach described in the previous section was applied to the two TSDF discussed earlier. Three annual simulations were performed for each facility in order to include effects of year-to-year variations in meteorology on the ambient concentration predictions. As noted earlier, the highest ambient concentration for each of the chemicals listed in Tables J-4 and J-5 were generated for each of the averaging times of concern (i.e., 15 min, 3 h, 8 h, 24 h, and annual).

The source data and receptor data required by the ISCST are very similar to that of the ISCLT discussed in Section J.5. Thus, the source data listed in Table J-14 and J-15 are the same as those used in the ISCST application. Similarly, the same receptor networks were used in both applications as well, and these are shown in Figures J-4 and J-5. The other major type of input data is the meteorological data. For the ISCST applications described here, data were obtained from NWS sites and preprocessed with the meteorological preprocessor referenced earlier. Other relevant ISCST options used in the model applications are described in Table J-17.

As described earlier, the short-term modeling approach for the acute health effects assessment was designed explicitly to estimate the highest ambient concentrations of each waste constituent at the two TSDF. Tables J-18 and J-19 have been prepared to summarize these results. These tables show the total annual average emissions on a facility basis for each of the constituents included in the analysis. They also show the highest ambient concentration estimates found in the three annual simulations for each of the averaging times of concern. Note that the ambient concentration estimates for a given constituent decrease with increasing averaging time. Further, a comparison of the predictions for different chemicals reveals that ambient concentration estimates are not necessarily proportional to total facility emissions. This occurs because ambient concentrations are affected by such factors as the characteristics of the emission release (e.g., height, horizontal area), the location of the release relative to facility fenceline, and the meteorology. Thus, direct comparisons of results for individual constituents and facilities may be inappropriate. For a discussion of how these levels compare with available health data, the reader is referred to Appendix E.

Urban dispersion mode 3 used.

Terrain effects not included (i.e., no elevated receptors).

Meteorological data selected from preprocessed NWS data.

Default wind profile exponents and vertical temperature gradient values used.

For point sources unaffected by adjacent buildings, final plume rise, stack tip downash, and buoyancy-induced dispersion used.

Decay coefficient set to zero.

ISCST calms processing routine used in the calculation of all ambient concentrations.

ISCST = Industrial Source Complex Short-Term.
NWS = National Weather Service.

	Average emissions.	н	ighest estimate	d ambient conce	ntrations by ave	araging time. <i>U</i> m	n/m3
Waste constituent	Mg/yr	15 min	1 h	3 h	8 h	24 h	Annual
1,1,1-Trichloroethane	1.0×10^1	1.5×10^{3}	1.2 × 10 ³	4.8×10^{2}	2.6×10^2	1.2×10^{2}	1.2×10^{1}
1,1,2-Trichloroethane	6.9×10^{-1}	9.7×10^{1}	7.7×10^{1}	3.2×10^1	1.8×10^{1}	8.3	8.0 × 10 ⁻¹
1,2-Dichloroethane	1.5×10^{-1}	2.0×10^1	1.8×10^{1}	8.7	3.7	1.8	1.7 × 10 ⁻¹
1,4-Dioxane	3.2×10^{-2}	4.5	3.6	1.5	8.1×10^{-1}	3.9×10^{-1}	3.7×10^{-2}
Acetic acid	7.3×10^{-1}	1.0×10^{3}	7.8×10^2	2.6×10^2	1.3×10^{2}	4.5×10^{1}	4.6
Acetone	8.1	1.0×10^{3}	8.2×10^2	3.7×10^{2}	2.0×10^2	1.0×10^{2}	9.5×10^{0}
Aniline	2.0×10^{-3}	2.0×10^{-1}	1.6×10^{-1}	1.1×10^{-1}	4.5 × 10 ⁻²	2.6×10^{-2}	3.1×10^{-3}
Benza I dehyde	1.8×10^{-2}	1.6×10^{1}	1.2×10^{1}	5.6	2.9	1.1	1.5 × 10 ⁻¹
Benzene	1.3×10^{-2}	1.6	1.3	6.1×10^{-1}	3.1×10^{-1}	1.7×10^{-1}	1.6×10^{-2}
Butanol	3.4×10^{-2}	4.2	3.4	2.0	9.3 × 10 ⁻¹	5.1 × 10 ⁻¹	5.4 × 10 ⁻²
Carbon tetrachloride	6.4 × 1Ø ⁻³	8.7×10^{-1}	8.9 × 10 ⁻¹	2.9×10^{-1}	1.6×10^{-1}	7.5 × 10-2	7.3 × 10 ^{~3}
Chlorobenzene	2.0	2.8×10^{3}	2.1×10^{3}	7.2×10^2	3.4×10^2	1.2×10^{2}	1.2×10^{1}
Chloroform	Б.Ø x 10 ⁻²	7.0	Б.8	2.3	1.3	6.0×10^{-1}	5.8 × 10 ⁻²
Cumene	2.0×10^{-2}	2.8×10^{1}	2.1×10^{1}	7.2	3,4	1.2	1.2×10^{-1}
Cyanide	1.8×10^{-1}	8.8×10^{1}	7.0×10^{1}	3.8×10^{1}	2.2×10^{1}	1.4×10^{1}	1.3
Dichlorobenzene	1.8×10^{-2}	1.8	1.4	1.0	4.1×10^{-1}	2.2×10^{-1}	2.7×10^{-2}
Ethyl acetate	5.3	1.1 × 10 ³	8.5×10^2	3.8×10^2	2.4×10^2	9.3×10^1	1.7×10^{1}
Ethyl alcohol	6.1 × 10 ⁰	1.4×10^{3}	1.1×10^{3}	4.9×10^2	3.3×10^2	1.5×10^{2}	3.4×10^2
Ethyl benzene	9.2	1.4×10^{4}	1.0×10^{4}	3.5 × 10 ³	2.1×10^{3}	6.5×10^2	5.3 x 10 ¹
Formaldehyde	2.0×10^{-2}	6.5	4.9	1.6	6.5×10^{-1}	2.2×10^{-1}	1.9×10^{-2}
Gasoline	1.8×10^{-2}	6.6 × 10 ¹	3.3×10^{1}	1.1×10^{1}	4.2	1.5	5.8 × 10 ⁻²
Isobuty! alcohol	5.8 × 10 ⁻²	7.4	5.8	3,5	1.8	8.8×10^{-1}	9.4×10^{-2}
Isopropanoi	1.5	1.8×10^{2}	1.4×10^{2}	6.7×10^{1}	3.4×10^{1}	1.9×10^{1}	1.8
Methanol	3.2	3.8×10^2	3.0×10^2	1.4×10^{2}	7.4×10^{1}	4.0×10^{1}	3.8
Methyl acrylate	1.4 × 10 ⁻³	1.4×10^{-1}	1.1 × 10 ⁻¹	7.9 × 10 ⁻²	3.1×10^{-2}	1.8 × 10 ⁻²	2.2×10^{-3}
Methyl ethyl ketone	1.2×10^1	1.4×10^{3}	1.1 × 10 ³	5.3 × 10 ²	2.7×10^{2}	1.5 × 10 ²	1.4×10^{1}

TABLE J-18. SUMMARY OF RESULTS FOR ACUTE HEALTH EFFECTS MODELING ANALYSIS OF SITE 1

(continued)

	Average								
	emissions,	Highest estimated ambient concentrations by averaging time, μ m/m3							
Waste constituent	Mg/yr	15 min	1 h	3 h	8 h	24 h	Annual		
Methy isobutyl ketone	5.7 × 10 ⁻²	8.1	4.8	3.3	1.4	7.6×10^{-1}	9.0 × 10-2		
Methyl methacrylate (R,T)	1.4 × 10 ⁻¹	1.9 × 10 ¹	1.6×10^{1}	6.1	3.4	1.8	1.6 × 10 ⁻¹		
Methylene chloride	7.8	3.0 × 10 ³	2.3×10^3	7.7×10^2	5.0 × 10 ²	1.5×10^{2}	1.6×10^{1}		
Perchloroethylene	2.3	3.2×10^2	2.5 x 10 ²	1.0×10^2	5.7×10^{1}	2.7×10^{1}	2.8		
Phenol	7.3×10^{-3}	7.0	б.б	2.4	1.6	8.3×10^{-1}	7.0×10^2		
Propanol	1.5×10^{-3}	1.9×10^{-1}	1.5×10^{-1}	6.8 × 10 ⁻²	3.5 × 10 ⁻²	1.8×10^{-2}	1.8×10^{-3}		
Styrene	2.3×10^{1}	3.5 × 10 ⁴	2.8×10^4	8.9×10^3	Б.7 × 10 ³	1.7×10^{3}	1.3×10^{2}		
Toluene	1.6×10^1	2.7×10^3	2.0×10^{3}	7.2×10^2	4.7×10^{2}	1.8×10^{2}	2.2×10^{1}		
Toluene diisocyanate	2.8 x 10 ⁻³	3.5 × 10 ⁻¹	2.8×10^{-1}	1.7×10^{-1}	7.7×10^{-2}	4.1×10^{-2}	4.4 × 10 ⁻³		
Trichloroethylene	5.8	8.2×10^{2}	6.5×10^{2}	2.7×10^{2}	1.5×10^{2}	7.0×10^{1}	6.7		
Trichlorotrifluoroethane	2.1	3.0×10^{2}	2.4×10^{2}	9.8×10^{1}	5.4×10^{1}	2.8×10^{1}	2.6		
Xylene	1.5	9.3×10^{2}	7.05 × 10 ²	2.4×10^{2}	1.5×10^{2}	4.4×10^{1}	4.4		

	Average emissions,	н	ighest estimate	Highest estimated ambient concentrations by averaging time, μ m/m3							
Waste constituent	Mg/yr	15 min	1 h	3 h	8 h	24 h	Annual				
1,2,3-Trichloropropane	2.4×10^{-7}	4.Б × 10 ⁻⁶	3.4 × 10 ⁻⁶	1.3 × 10 ⁻⁶	9.9 × 10 ⁻⁷	3.7 × 10 ⁻⁷	2.3 × 10				
1,2-Dichloroethane	4.9×10^{-1}	1.6×10^{1}	1.2×10^{1}	4.2	1.8	6.3×10^{-1}	2.2 × 10				
1,4-Dioxane	7.1 × 10 ⁻⁶	1.5×10^{-4}	1.Ø × 10 ⁻⁴	4.8 × 10 ⁻⁵	3.7 × 10 ⁻⁵	1.4×10^{-5}	6.5 × 10				
Acetic acid	3.0	2.7×10^{1}	2.1×10^{1}	1.3×10^{1}	5.5	2.2	1.7 × 10				
Acetone	4.5×10^{-1}	4.0	2.7	1.7	1.2	8.7×10^{-1}	6.7 × 10				
Acetophenone	5.9 × 10 ⁻⁷	1.1×10^{-5}	8.4 × 10 ⁻⁶	2.9 × 10 ⁻⁶	2.2 × 10 ⁻⁶	8.8×10^{-7}	5.4 x 10				
Acrylonitrile	6.6 × 10 ⁻⁶	1.2×10^{-4}	B.Ø × 10 ⁵	4.6 × 10-Б	3.8×10^{-5}	1.4 × 10 ⁻⁵	6.1 x 10 ⁻				
Aniline	3.6×10^{-1}	1.3×10^{1}	9.9	6.1	Б.2	2.4	1.0 x 10				
Benzene "	7.0 × 10 ⁻³	1.4	1.1	3.6×10^{-1}	1.3×10^{-1}	4.4×10^{-2}	1.0 × 10				
Bromomethane	2.4×10^{-1}	Б.4	4.1	1.4	5.9 × 10 ⁻¹	2.1×10^{-1}	9.3 x 10				
Carbon tetrachioride	6.1×10^{-1}	1.2×10^2	9.3×10^1	3.1×10^1	1.1×10^{1}	3.9	6.7 × 10				
Chlorobenzene	2.3×10^{-1}	2.0	1.8	9.3 × 10-1	4.1×10^{-1}	1.6×10^{-1}	1.1 × 10				
Cumene	7.0×10^{-3}	1.1	6.7×10^{-1}	2.2×10^{-1}	9.8 × 10 ⁻²	3.3 × 10 ⁻²	1.0 × 10				
Dichlorobenzene	4.2×10^{-6}	8.9 × 10 ⁻⁵	8.7 × 10 ^{−5}	2.3 × 10 ^{-Б}	1.4 × 10 ⁻⁵	7.0 x 10 ⁻⁶	3.9 × 10				
Diethyl amine	7.4×10^{-2}	2.9	2.3	1.3	5.8 × 10 ⁻¹	2.2×10^{-1}	2.1 × 10				
Dimethyl formamide	9.5	1.5 × 10 ²	7.8×10^{1}	Б.1 × 10 ⁻¹	3.5 × 10 ¹	2.7×10^{1}	2.0				
Ethyi alcohol	6.3 × 10 ⁻⁶	1.3 × 10 ⁻⁴	8.4 × 10 ⁻⁵	3.3 × 10 ⁻⁵	2.6 × 10 ⁻⁵	9.8 × 1Ø ⁻⁸	5.8 x 10				
Ethylene glycol	1.7×10^{-2}	2.9×10^{-1}	2.0×10^{-1}	9.2 × 10 ⁻²	7.3×10^{-2}	2.8×10^{-2}	1.3 × 10				
^F orma i dehyde	9.2×10^{-1}	8.1	6.4	3.9	1.9	8.5 x 10 ⁻¹	9.9 × 10				
Formic acid	2.5×10^{-2}	0.8×10^{-1}	6.8 × 10 ⁻¹	4.2×10^{-1}	3.6×10^{-1}	1.7 × 10 ⁻¹	6.9 x 10				
lycerin	6.2 × 10 ⁻³	2.2×10^{-1}	1.7×10^{-1}	1.1×10^{-1}	9.1×10^{-2}	4.1 × 10 ⁻²	1.7 × 10				
Slycidol	9.3 × 10 ⁻³	3.3×10^{-1}	2.5×10^{-1}	1.6×10^{-1}	1.3×10^{-1}	6.1 × 10 ⁻²	2.6 × 10				
lexach l oroethane	5.0 × 10 ⁻⁵	9.2×10^{-4}	7.0×10^{-4}	2.6×10^{-4}	2.0×10^{-4}	7.7 × 10 ⁻⁵	4.6 × 10				
lydrazîne	3.1×10^{-3}	1.1 × 10 ⁻¹	8.5×10^{-2}	5.2 × 10 ⁻²	4.5×10^{-2}	2.0 x 10 ⁻²	8.7 x 10				
sopropanol	4.7×10^{-1}	4.0	3.1	2.0	9.3 × 10 ⁻¹	4.4×10^{-1}	5.2 × 10				
aleic anhydride	7.7 × 10-10	2.6 x 10 ⁻⁸	2.0×10^{-9}	6.8 x 10 ⁻⁹	3.9 × 10 ⁻⁹	2.0×10^{-9}	7.0 × 16				
ethacrylic acid (MAA)	3.9×10^{-7}	7.3 x 10 ⁻⁶	5.5 × 10 ⁻⁶	1.9×10^{-6}	1.5 x 10 ⁻⁶	Б.9 x 10 ⁻⁷	3.6 x 16				
ethanol	1.0×10^{-1}	3.7	2.8	1.8	15	87×10-1	2.9 y 14				

TABLE J-19. SUMMARY OF RESULTS FOR ACUTE HEALTH EFFECTS MODELING ANALYSIS OF SITE 2

	Average emissions,	Highest estimated ambient concentrations by averaging time, μ m/m3							
Waste constituent	Mg/yr	15 min	1 h	3 h	8 h	24 h	Annual		
Methyl ethyl ketone	4.6×10^{-1}	4.0	3.2	2.0	9.3×10^{-1}	4.3×10^{-1}	5.0 × 10 ⁻²		
Methylene chloride	2.7	3.1×10^1	2.4×10^{1}	1.4×10^{1}	6.3	2.2	6.4 × 10 ⁻²		
n-propanol	9.4×10^{-6}	1.9×10^{-4}	1.3×10^{-4}	4.7×10^{-5}	3.7 x 10 ⁻⁵	1.4 × 10 ⁻⁵	8.6 × 10 ⁻⁷		
Perchloroethylenø	7.3×10^{-4}	1.5×10^{-2}	1.0×10^{-2}	4.9×10^{-3}	3.8 x 10 ⁻³	1.4×10^{-3}	6.7 × 10-5		
Phenol	9.8×10^{-3}	3.5 × 10 ⁻¹	2.7×10^{-1}	1.7×10^{-1}	1.4×10^{-1}	6.4×10^{-2}	2.8 × 10 ⁻³		
Phthalic anhydride	2.2×10^{-4}	4.2×10^{-3}	3.2 × 10 ⁻³	1.1 × 10 ⁻³	8.5 × 10 ⁻⁴	3.3×10^{-4}	2.1 × 10-5		
p-chloroaniline	4.7×10^{-1}	1.1×10^{1}	8.2	2.8	1.2	4.3 x 10 ⁻¹	1.8 × 10 ⁻²		
Toluene	3.3×10^{-6}	5.9 × 10 ⁻⁵	4.0 × 10 ⁻⁵	2.3 × 10 ⁻⁵	1.8 × 10 ⁻⁵	6.8 × 10 ⁻⁶	3.1 × 10-7		
Trichloroethylene	1.4 × 10 ⁻⁵	3.0×10^{-4}	2.0×10^{-4}	9.5 × 10 ⁻⁵	7.5 x 10 ⁻⁵	2.8 x 10 ⁻⁵	1.3 × 10 ⁻⁶		
Vinyl acetate	2.4	2.1×10^1	1.5×10^{1}	8.7	6.1	3.5	3.5 x 10 ⁻¹		
Xylene	9.0	1.0×10^{2}	7.6×10^{1}	4.3×10^{1}	2.0×10^{1}	6.9	3.3×10^{-1}		

TABLE J-19. (continued)

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