&EPA

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

Draft EIS

Volume I-Chapters

PRELIMINARY DRAFT

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Emission Standards Division

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ABBREVIATIONS AND CONVERSION FACTORS

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

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

Frequently used measurements in this document are:

$$
\begin{array}{llllll}
0.21 & m^3 & \sim & 210\ L & \sim & 55\ gal \\
5.7 & m^3 & \sim & 5,700\ L & \sim & 1,500\ gal \\
30 & m^3 & \sim & 30,000\ L & \sim & 8,000\ gal \\
76 & m^3 & \sim & 76,000\ L & \sim & 20,000\ gal \\
800 & m^3 & \sim & 800,000\ L & \sim & 210,000\ gal \\
1.83 & kg\ O_2/kW/h & \sim & 3\ lb\ O_2/hp/h & & \\
& kW/28.3\ m^3 & \sim & 1.341\ hp/10^3\ ft^3 & & \\
& kPa{\cdot}m^3/g{\cdot}mol & \sim & 0.0099\ atm{\cdot}m^3/g{\cdot}mol & &
\end{array}
$$

3.0 INDUSTRY DESCRIPTION AND AIR EMISSIONS

This chapter presents a brief overview of the hazardous waste industry
and a summary description of the techniques used in estimating nationwide
organic air emissions for hazardous waste treatment, storage, and disposal
facilities (TSDF) in the United States. The hazardous waste industry and
TSDF emission sources are described in Section 3.1. The estimation of TSDF
nationwide emissions is presented in Section 3.2. Emission estimation
techniques include the development and use of (1) TSDF emission models,
which provide a mechanism for analyzing air emissions from TSDF management
processes and applicable emission control technologies, and (2) a computer
program developed to process the data and information on the TSDF industry
and to perform emission calculations based on the available data. Discus-
sions of air pollution controls and control strategies at TSDF follow in
Chapters 4.0 and 5.0, respectively.

3.1 THE HAZARDOUS WASTE INDUSTRY

The hazardous waste industry in the United States is diverse and com-
plex. The universe of hazardous waste generators represents a broad spec-
trum of industry types and sizes. Wastes generated vary considerably in
both composition and form; and the waste management processes and practices
used in treating, storing, and disposing of hazardous wastes are also
widely varied. Figure 3-1 presents a simplified waste system flow chart
for the hazardous waste industry. Key elements of the industry are: gene-
ration, transportation, treatment, storage, and disposal. The major ele-
ments of the hazardous waste industry are discussed in the following sec-
tions.

3.1.1 General Hazardous Waste Description

General waste descriptions include hazardous wastes in the following
forms: contaminated wastewaters, spent solvents residuals, still bottoms,

Generation	Transportation	Storage	Treatment	Disposal

RCRA Wastes Large & Small Quantities

INTERFIRM or INTRAFIRM Land & Water Transport

Drum Tank & Impound-ment Storage

Commercial Incinerators*

Onsite Incinerators*

Solvent & Other Recovery Operations

Other Treatment Operations†

Industrial Furnaces or Boilers*

Commercial Land Disposal

Onsite Land Disposal

Deep Well Injection

*Regulated by the Office of Solid Waste.

†Onsite and commercial.

Figure 3-1. Simplified hazardous waste system from generation to disposal.

spent catalysts, electroplating wastes, metal-contaminated sludges, degreasing solvents, leaded tank bottoms, American Petroleum Institute (API) separator sludges, off-specification chemicals, and a variety of other waste types. In reviewing waste data, more than 4,000 chemical constituents have been identified as being contained in the various waste types examined.[1]

Title 40 of the Code of Federal Regulations (CFR), Part 261.3 (40 CFR 261.3), defines hazardous waste as four categories:

- Characteristic wastes--wastes that exhibit any hazardous characteristic identified in 40 CFR 261 Subpart C, including: ignitibility, corrosivity, reactivity, or extraction procedure (EP) toxicity

- Listed waste--wastes listed in 40 CFR 261, Subpart D

- Mixture rule wastes--wastes that are (1) a mixture of solid waste and a characteristic waste unless the mixture no longer exhibits any hazardous characteristic, or (2) a mixture of a solid waste and one or more listed hazardous wastes

- Derived from rule wastes--any solid waste generated from the treatment, storage, or disposal of a hazardous waste, including any sludge, spill residue, ash, emission control dust, or leachate (but not including precipitation runoff).

Hazardous wastes are designated by Resource Conservation and Recovery Act (RCRA) alphanumeric codes. Codes D001 through D017 are referred to as "characteristic wastes." D001 represents wastes that are ignitible in character; D002, those that are corrosive; and D003, those that are reactive. Extracts of wastes that contain toxic concentrations of specific metals, pesticides, or herbicides are assigned one of the codes D004 through D017.

"Listed wastes" encompass four groups of alphanumeric codes published in 40 CFR 261, Subpart D. Hazardous wastes generated from nonspecific industry sources such as degreasing operations and electroplating are listed as codes beginning with the letter "F," e.g., F001. Hazardous wastes from specific generating sources such as petroleum refining are · assigned codes beginning with the letter "K," e.g., K048. Waste codes beginning with "P" or "U" represent waste commercial chemical products and manufacturing chemical intermediates (whether usable or off-specification)

40 CFR 261, "Identification and Listing of Hazardous Wastes," not only lists hazardous wastes but also identifies specific wastes that are excluded from regulation as hazardous. These excluded wastes can be stored, treated, or disposed of without a RCRA permit.

3.1.2 Generators

The overwhelming majority of hazardous wastes are produced by large-quantity generators, those firms that generate more than 1,000 kg of hazardous waste per month. It has been estimated that there are about 71,000 large-quantity generators of hazardous waste in the United States.[2] These generators account for 99 percent of the 275 million Mg/yr of hazardous waste produced and managed under RCRA in 1985.[3] Hazardous waste generators are most prevalent in the manufacturing industries (standard industrial classification [SIC] codes 20-39). Manufacturing as a whole accounts for more than 90 percent of the total quantity of hazardous waste generated. Among specific industries, the chemical, petroleum, metals, electrical equipment, and transportation industries are the major generators of hazardous wastes. Two industry groups that stand out as generators are the chemical and petroleum industries (SIC 28 and 29); these industries alone account for more than 70 percent of total waste generation. The chemical industry (SIC 28), with only 17 percent of the generators, generated 68 percent of all the hazardous wastes produced in 1981. Another prominent group in the manufacturing sector was metal-related industries (SIC 33-37); these industries generated about 22 percent of all hazardous wastes in 1981.[4]

The 1981 Survey of Hazardous Waste Generators and Treatment, Storage, and Disposal Facilities (Westat Survey)[5] showed that only 15 percent of the generators were nonmanufacturing or unclassified under SIC. The survey results also provide estimates of number of generators producing specific types of hazardous wastes. Just over half the generators indicated that they generate spent solvents, both halogenated and nonhalogenated (RCRA waste codes F001-F005). Generators of sludges from wastewater treatment systems associated with electroplating and coating operations and generators of quenching and plating bath solutions and sludges accounted for 16 percent of the generator population. Only 10 percent of the generators

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generated listed hazardous wastes from specific industrial sources (e.g., slop oil emulsion solids from the petroleum refining industry--K049). Forty-three percent of generators produce ignitible wastes (RCRA waste code D001), a third generated corrosive wastes (D002), and more than a quarter generated wastes that failed EPA's test for toxicity (D004-D017). Just under 30 percent of the generators reported hazardous wastes that were spilled, discarded, or off-specification commercial chemical products or manufacturing chemical intermediates ("P" and "U" prefix waste codes).

The physical characteristics of the 275 million Mg of RCRA hazardous waste managed in 1985 vary from dilute wastewater to metal-bearing sludges to soils contaminated with polychlorinated biphenyl (PCB). Over 90 percent (by weight) of RCRA hazardous waste is in the form of dilute aqueous waste. The remaining wastes are organic and inorganic sludges and organic and inorganic solids. Figure 3-2 categorizes hazardous waste by physical characteristics.

Although small-quantity generators (those that generate more than 100 kg and less than 1,000 kg of hazardous waste per month) represent a large proportion of the number of hazardous waste generators nationally (more than 26,000),[7] they account for only a very small fraction of the hazardous wastes generated. About 25 percent of the country's hazardous waste generators are small-quantity generators, but these generators contribute less than one-half of 1 percent of the total hazardous waste generated.[8] The majority of the small-quantity generators are automotive repair firms, construction firms, dry cleaners, photographic processors, and laboratories. The wastes produced by small-quantity generators span the full spectrum of RCRA hazardous wastes. According to EPA's National Small Quantity Hazardous Waste Generator Survey,[9] the majority of small-quantity generator waste is derived from lead acid batteries; the remainder includes such hazardous wastes as acids, solvents, photographic wastes, and dry cleaning residues.

3.1.3 Transporters

Once a RCRA hazardous waste is generated, it must be managed (i.e., stored, treated, or disposed of) in accordance with legal requirements. Although nearly all hazardous waste is managed to some degree at the site

Organic Sludges (2×10^6 Mg)

Organic Liquids
(4×10^6 Mg)

Inorganic Solids
(2×10^6 Mg)

Aqueous Sludges
(15×10^6 Mg)

Aqueous Liquids
(252×10^6 Mg)
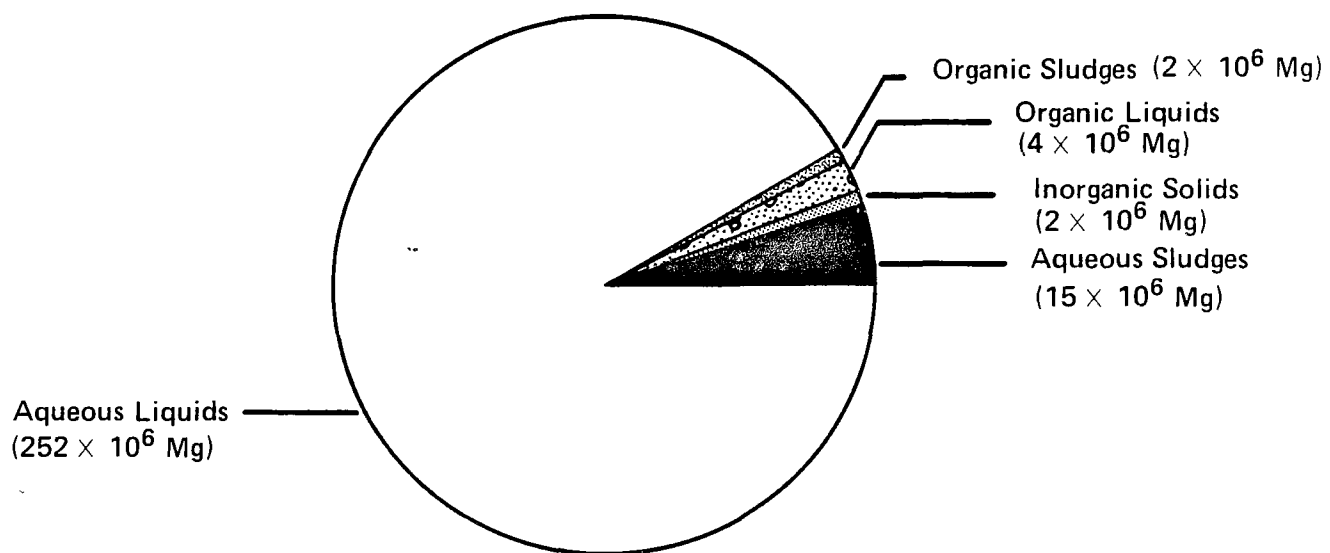
Figure 3-2. Estimate of physical characteristics of RCRA hazardous wastes.[6]

where it is generated, the Westat Survey has shown that only about one in six generators manage their hazardous waste exclusively onsite.[10] Of those generators that ship hazardous wastes to offsite management facilities for treatment, storage, and disposal, roughly a quarter still manage part of their hazardous wastes onsite. Although the survey estimated that 84 percent of the generators ship some or all of their hazardous wastes offsite, the vast majority of the quantities of hazardous waste are nonetheless managed onsite. Data supplied by generators indicate that about 96 percent of all generated hazardous wastes are managed onsite, with only 4 percent being shipped offsite for treatment, storage, or disposal.

In response to the movement of hazardous waste, a large industry has developed that transports hazardous wastes from generators to TSDF. It has been estimated that over 13,000 transporters are involved in moving hazardous wastes by land or water from generators to TSDF.[11]

3.1.4 Treatment, Storage, and Disposal Facilities

A significant segment of the hazardous waste industry is involved in hazardous waste management (i.e., treatment, storage, and disposal activities). Table 3-1 provides the RCRA definition of treatment, storage, and disposal. TSDF must apply for and receive a permit to operate under RCRA Subtitle C regulations. The RCRA Subtitle C permit program regulates 13 categories of waste management processes. There are four process categories each within storage and treatment practices and five categories within disposal practices. Table 3-2 presents the 13 major categories by RCRA process code.

Some of the 13 RCRA process categories can be further classified by characteristics of the waste management processes. For example, tank treatment may be quiescent or agitated/aerated (referring to the presence or lack of movement/mixing of the liquid contained in the tank). Such process varieties and similarities are reflected in the characterization of the industry when estimating nationwide TSDF emissions. Figures 3-3 through 3-5 provide a more detailed look at examples of the various management processes. As can be seen from the range of treatment and disposal processes, the industry is complex and not easily characterized. The hazardous waste industry is also dynamic; that is, in response to

TABLE 3-1. RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)
HAZARDOUS WASTE MANAGEMENT DEFINITIONS[a]

Term	Definition
Storage	"Storage" means the holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere.
Treatment	"Treatment" means any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or so as to recover energy or material resources from the waste, or so as to render such waste non-hazardous, or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume.
Disposal facility	"Disposal facility" means a facility or part of a facility at which hazardous waste is intentionally placed into or on any land or water, and at which waste will remain after closure.

[a]Definitions are presented as stated in RCRA regulations (40 CFR 260.10) as of July 1, 1986.[12]

TABLE 3-2. NATIONWIDE QUANTITY OF HAZARDOUS WASTE MANAGED BY
SPECIFIC PROCESSES

Waste management process	RCRA process code	Number of active facilities with process[a]	Waste quantity managed,[a] 10^6 Mg/yr
Storage			133
Container	S01	1,440	
Tank	S02	911	
Wastepile	S03	57	
Impoundment	S04	223	
Treatment			154
Tank	T01	291	
Impoundment	T02	127	
Incineration	T03	158	
Other[b]	T04	319	
Disposal			49
Injection well	D79	61	
Landfill	D80	90	
Land treatment	D81	54	
Ocean disposal	D82	NA	
Impoundment	D83	47	
Total[c]		>2,300	275

RCRA = Resource Conservation and Recovery Act.
 NA = Not available.

[a]Based on the 1986 Screener Survey.[13] Excludes facilities that manage less than 0.01 Mg/yr in storage, treatment, and disposal processes. Quantities were not reported in this survey by specific management process.

[b]"Other" refers to physical, chemical, thermal, or biological treatment processes not occurring in tanks, surface impoundments, or incinerators.

[c]Facilities do not add up to about 2,300 because some facilities have more than one process. Waste quantities presented do not add to the total of 275 million Mg of hazardous waste produced and managed in 1985 because some facilities may process a waste in more than one management process. For example, a waste may be stored prior to treatment or treated prior to disposal.
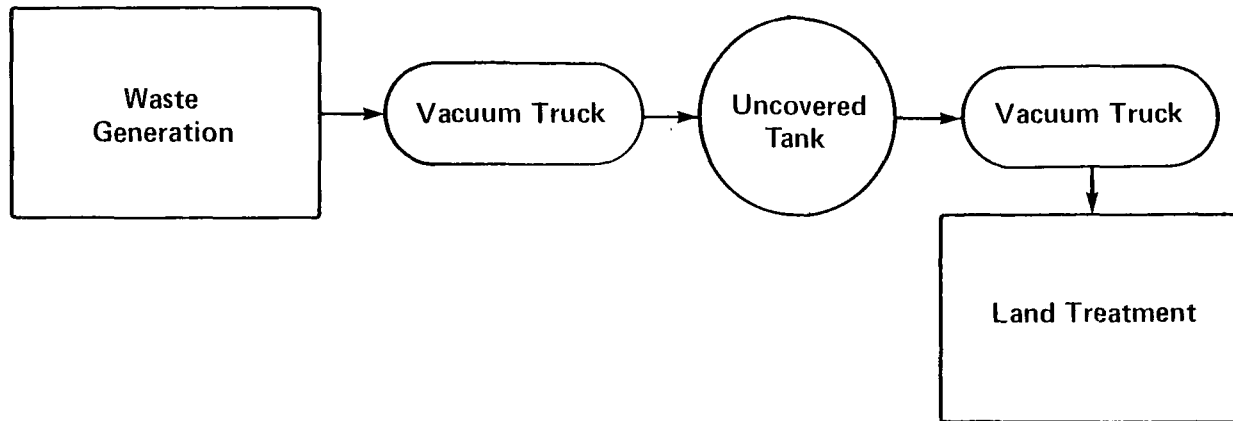
A. Land treatment of bulk sludges or liquids
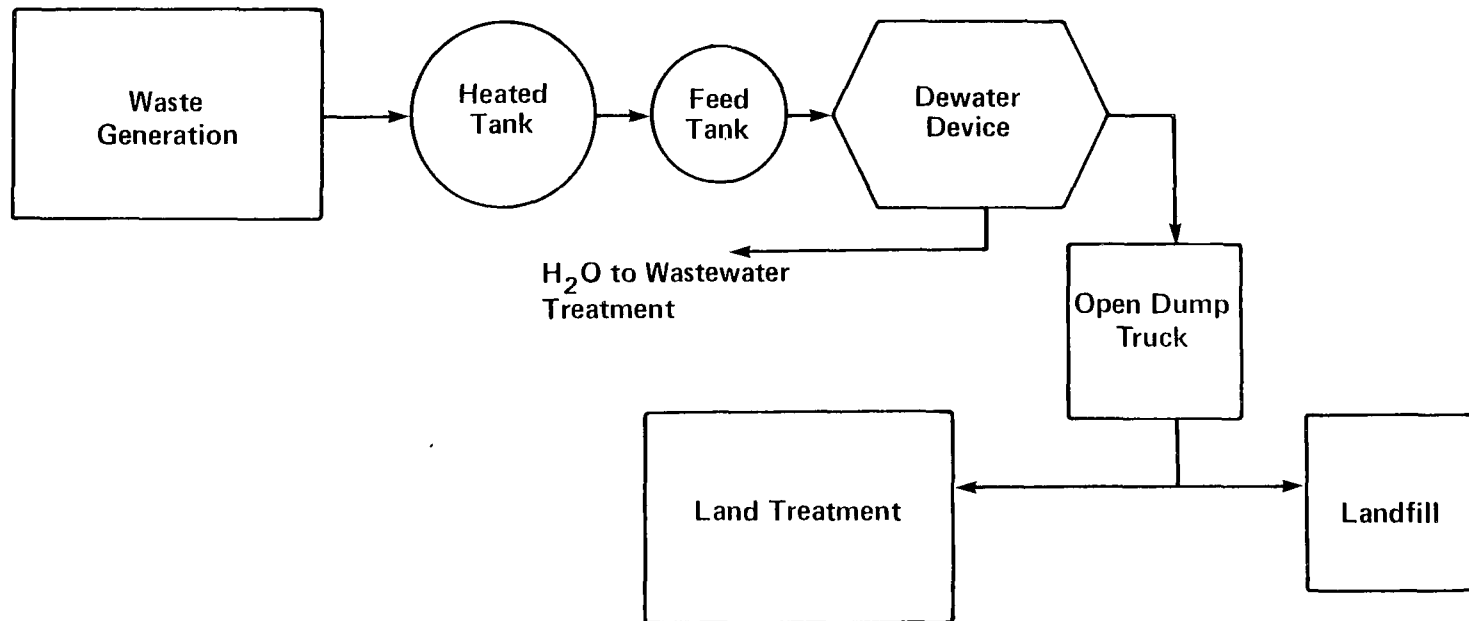
B. Land treatment of filtered solids

Figure 3-3. Two examples of onsite hazardous waste land treatment operations.
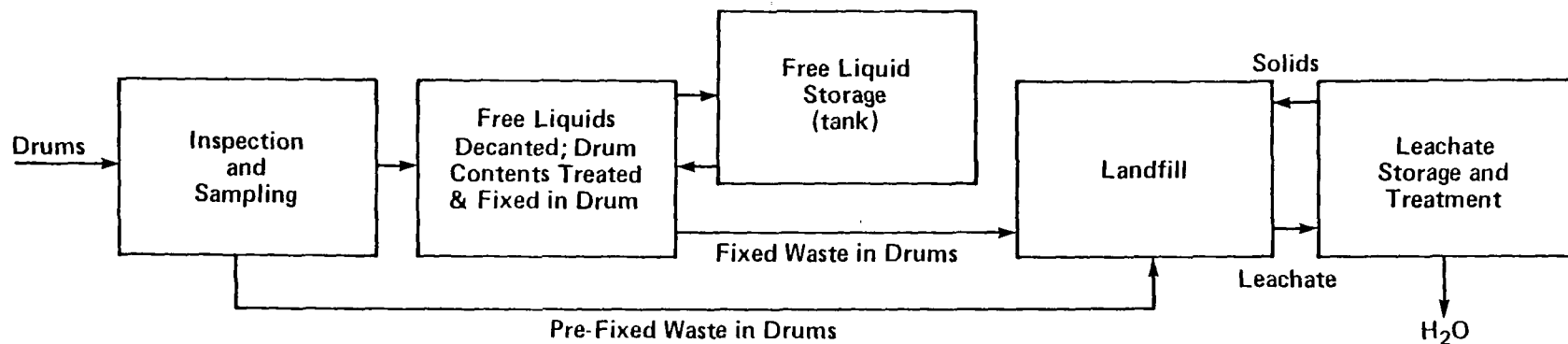
A. Drum disposal
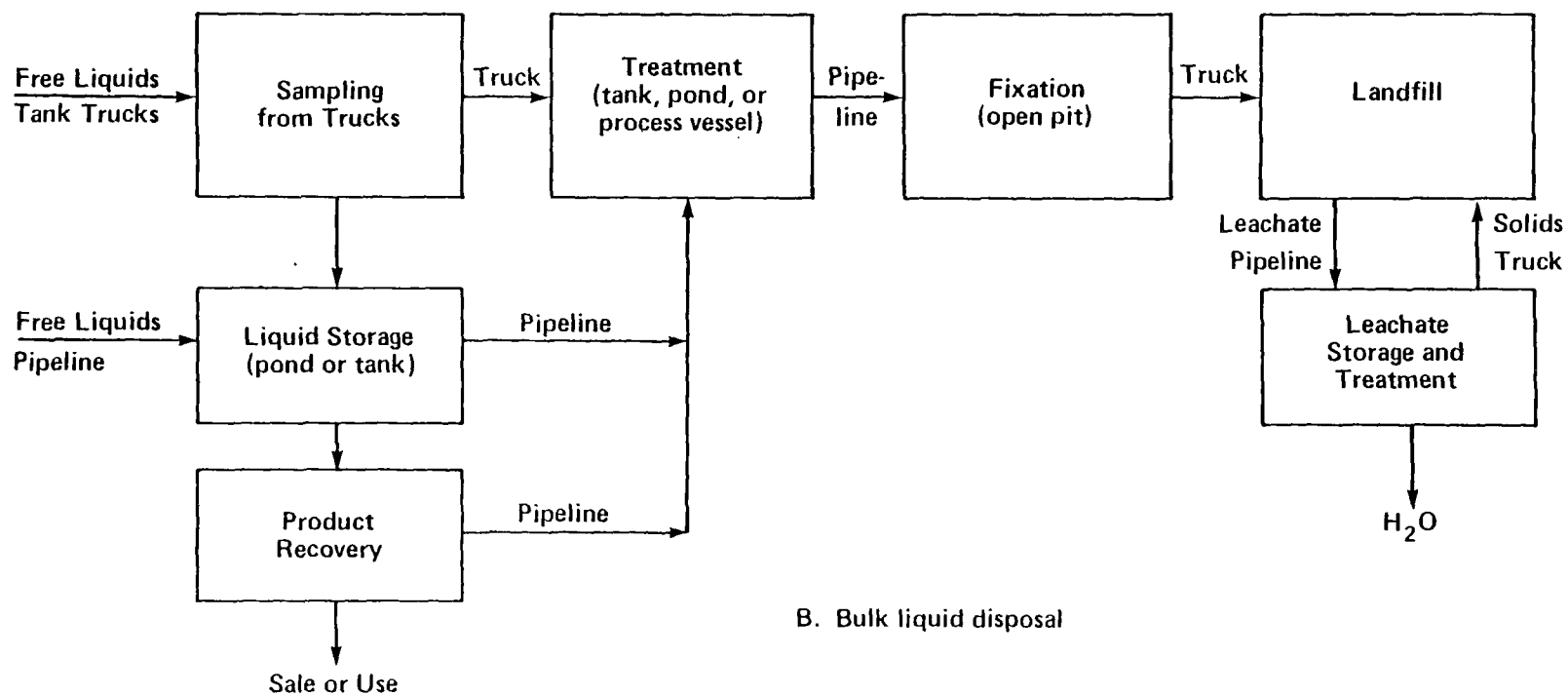
B. Bulk liquid disposal

Figure 3-4. Two examples of active landfill operations.
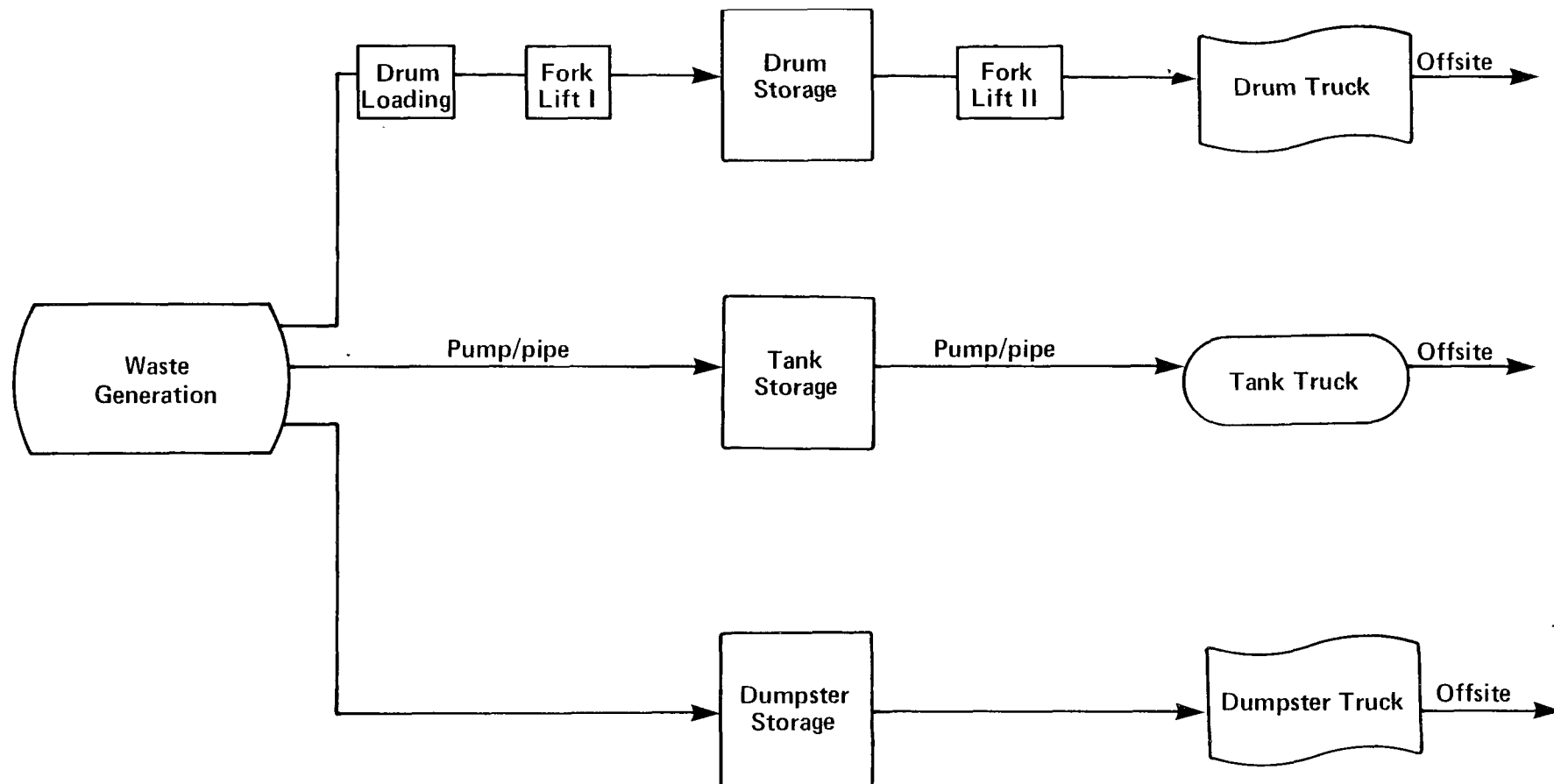
Figure 3-5. Example onsite hazardous waste storage facility.

changing demands and regulations, the facilities change the ways wastes are treated, stored, and disposed of.

The total estimated quantity of hazardous wastes managed at more than 2,300 TSDF in 1985 was 275 million Mg. The waste quantities handled by each of the three main waste management processes (i.e., treatment, storage, and disposal) are presented in Table 3-2. The waste quantities given in Table 3-2 will not sum to the total national estimate because some wastes pass through more than one process; for example, a waste may be stored prior to treatment or treated prior to disposal. Also provided in Table 3-2 is a breakdown of the number of active TSDF by specific type of treatment, storage, or disposal process. In the storage category, container storage is a management process utilized by more than half the TSDF; tank storage occurs at slightly more than a third of the TSDF. Of the treatment processes, tank treatment is widely practiced, but no single treatment process is used in a majority of facilities. In the disposal category, landfills are the dominant disposal units operated at TSDF.

The information presented above is taken from a TSDF data base of waste management practices compiled for use in examining the industry and its environmental and health impacts. Three data bases were used to generate this TSDF data base. Two major sources were the Hazardous Waste Data Management System (HWDMS)[14] and the 1981 Westat Survey, both of which are EPA Office of Solid Waste (OSW) data bases. More recent information from the OSW 1986 National Screening Survey of Hazardous Waste Treatment, Storage, Disposal, and Recycling Facilities (1986 Screener) was also used to make the TSDF data base as current as possible.[15] Each of these three data bases provided a different level of detail regarding particular aspects of the TSDF industry. For example, the HWDMS provided waste management process codes, wastes codes, and facility SIC codes. The 1986 Screener provided information on total annual waste quantities managed by the facility and operating status (active or closed) for the entire industry. The Westat Survey, on the other hand, deals with only a subset of the industry but provides a greater level of detail regarding individual facility operations; for example, the distribution of waste quantities handled by each waste management process is available for each facility in the data base.

3.1.5 TSDF Emission Sources

The organic emission sources associated with each type of storage, treatment, and disposal process are summarized in Table 3-3. The emission sources in this table are arranged into seven categories based on their common emission characteristics and/or their routine association with other processes. These are (1) impoundments and tanks, (2) land treatment, (3) landfills and wastepiles, (4) transfer and handling operations, (5) injection wells, (6) incinerators, and (7) organic compound removal devices.

For open (or uncovered) surface impoundments and tanks, the major source of organic emissions is the uncovered liquid surface exposed to the air. The conditions under which liquids are stored in uncovered impoundments and uncovered tanks ranges from quiescent to highly turbulent since, in some cases, aeration and/or agitation are applied to aid in treatment of the waste. Emissions tend to increase with an increase in surface turbulence because of enhanced mass transfer between the liquid and air. For both uncovered and covered storage tanks, loading and breathing losses are a major source of emissions.

At land treatment facilities, wastes are either spread on or injected into the soil, after which they are normally tilled into the soil. Other activities that are likely to occur at land treatment facilities include transfer, storage, handling, and dewatering of the wastes to be land-treated. Examples would include loading and unloading of wastes in vacuum trucks and dewatering of wastes using one of the various types of available filtration devices. Each of the land treatment process stages illustrated in Figure 3-3 is a potential source of organic air emissions. The major emission source associated with land treatment is the land treatment area itself.

A landfill is a facility, usually an excavated, lined pit or trench, into which wastes are placed for disposal. Some existing landfills may not be lined; however, all new facilities are lined to meet RCRA permit requirements. All wastes containing liquids and destined for disposal in a landfill must be treated or "fixed" to form a nonliquid material. Landfills are a source of organic emissions from several emission points.

TABLE 3-3. HAZARDOUS WASTE MANAGEMENT PROCESS EMISSION SOURCES

Management process	Emission source
Impoundments and Tanks	
(S04, T02, D83) (S02, T01)	
Quiescent impoundments (storage & treatment)	Quiescent liquid surface
Quiescent tanks (storage & treatment)	
Uncovered	Quiescent liquid surface
Covered	Working and breathing lossses
Aerated/agitated impoundments (treatment)	Turbulent liquid surface
Aerated/agitated uncovered tanks (treatment)	Turbulent liquid surface
Impoundment lining	Dredging (exposed waste surface)[a]
Impoundment inlet	Splash loading[b]
Land Treatment (D81)	
Land application	Application of waste to soil Applied waste before tilling Applied waste after tilling
Dewatering devices	Vacuum pump exhaust for vacuum filters[a] Exposed waste surface in belt filter presses Filter cake collection and disposal
Landfills (D80) and Wastepiles (S03)	
Active landfill	Transport of waste to landfill (open trucks) Unloading and spreading of wastes Landfilled waste Leachate (within the confines of the liner system)

(continued)

TABLE 3-3 (continued)

Management process	Emission source
Landfills and Wastepiles (con.)	
Closed landfill	Landfill surface gas vents and manholes Leachate (within the confines of the liner system)
Wastepiles	Wastepile surface Leachate (within the confines of the liner system)
Waste fixation	
Pit and mixer	Splash loading into fixation pits[b] Mixing of waste and fixative Mechanical mixer vents
Drum	Drum inspection[a] Drum decanting[a] In-drum fixation[a]
Transfer and Handling Operations (S01, S02)	
Vacuum trucks	Vacuum pump exhaust Spills during truck loading Truck cleaning[a]
Open dump trucks	Waste surface during loading and transport Spills Truck cleaning[a]
Equipment leaks[c]	Losses from pumps, valves, sampling connections, open-end lines, and pressure-relief devices
Containers	

Drums
   Tank trucks
   Railroad tank cars
   Marine tankers
   Barges
   Dumpsters
	Waste loading
	Spillage in transit
	Spillage during waste loading/unloading
	Exposed waste surface
	Cleaning losses[a]

(continued)

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TABLE 3-3 (continued)

Management process source category	Emission source
Injection Wells (D79)[d]	
Incinerators (T03)[e]	Exhaust gas stacks
Organic Compound Removal (Treatment)[f] Devices	Process vents Condenser vents Equipment leaks (pumps, valves, etc.)

[a]No emission estimating method exists for this source.

[b]No emission estimating method exists for this source. Unlike enclosed sources such as tanks, this is an open source and vapor saturation does not occur.

[c]Emissions from equipment leaks are associated with all management processes that involve the use of pumps, valves, sampling connections, open-ended lines, and pressure-relief devices.

[d]This management process is being regulated under a different standard. The equipment leak emissions related to the injection well disposal process are evaluated in this document.

[e]Incinerator emission sources, such as exhaust gas stacks, are regulated under 40 CFR 264, Subpart O, "Incinerators." The equipment leak emissions related to incineration are evaluated in this document.

[f]These devices are chemical process units that are designed to reduce the organic content of a waste. Typically, these processes are employed for the recovery of valuable organics for recycle and reuse; in relation to environmental protection, these processes are or can be used for pollution control. For example, organics may be removed to make a waste suitable for hazardous waste land disposal.

Figure 3-4 shows typical process stages for two variations in landfill processing; each of the processing steps identified is a potential emission source. The landfill surface, whether open, covered with earth daily, or closed with a cap is an emission source. A waste fixation pit is another source of organic emissions that could be associated with landfills. Activities at the landfill, such as waste transport and waste unloading and spreading, are also sources of emissions. Wastepiles are similar to landfills and the same emission sources can be found; they are, in essence, temporary landfills.

Each of the process steps illustrated in Figure 3-5 is a potential emission source associated with hazardous waste transfer, storage, and handling operations. Loading operations contribute to overall emissions, especially splash loading of waste as opposed to submerged loading. Spills also occur during waste transfer and handling and, for liquid wastes that are pumped, emissions may occur from fugitive sources such as pumps and valves or at open-ended lines, pressure-relief valves, and sampling connections. Organic emissions are associated with all three of the storage methods shown in Figure 3-5: drums, dumpsters, and tanks.

Miscellaneous sources of emissions such as drum cleaning or the crushing and landfilling of empty drums containing waste residues also contribute to organic air emissions. The improper handling of drum residue can lead to emissions along with waste residues lost to the environment by uncontained drum crushing operations. In addition, RCRA permit conditions require annual dredging of surface impoundments; the dredging operation, a waste transfer process, may also be a source of organic emissions.

3.2 ESTIMATES OF ORGANIC EMISSIONS

A modeling approach based on applicable mass transfer equations was selected as the method of estimating organic emissions from TSDF. Models initially developed by the EPA Office of Solid Waste were refined to incorporate inputs relevant to estimating air emissions. The models selected for use are formulated for individual management processes at TSDF and account for such factors as process design and operating parameters as well as the meteorological effects on emissions. These emission models were used to generate estimates of the amounts of organics in the incoming

wastes that are emitted to the air or biodegraded during processing. More traditional emission estimating techniques and methodologies, such as basing emission estimates on the results of a limited number of actual TSDF source tests, are not appropriate for the diverse operations found in this industry. The TSDF industry and its waste management processes are too varied to use source test data as the sole basis to estimate industry-wide emissions.

The use of emission models makes it possible to generate emission estimates under a wide variety of source conditions and waste compositions. The accuracy of estimates made by the emission models in comparison to actual field measurements of emissions for specific sites has been examined. That comparison is discussed in Appendix C. In general, it was found that, where comparisons could be made, emission model estimates compared favorably with field data. Appendix F contains the TSDF source test data.

The following sections describe the bases for developing estimates of organic compound emissions from TSDF using the modeling approach. Section 3.2.1 discusses the elements necessary for producing nationwide emission estimates for individual waste management units. Section 3.2.2 discusses how those elements are combined in a single computer model to produce the nationwide emission estimates.

3.2.1 <u>Emission Estimation Data Requirements</u>

Key elements in the estimation of organic emissions from TSDF are the availability of: (1) facility-specific information, (2) management process emission characteristics, and (3) waste compositions. Facility-specific information and data include the types of waste management processes present in those facilities, the RCRA waste codes managed at the facilities, and the total quantity of waste managed for each of the facilities nationwide. Some facility-specific information is available through data bases established for other EPA projects (e.g., the HWDMS, the 1981 Westat Survey, and the 1986 Screener). Where facility-specific data are insufficient, estimated values based on typical industry wastes and operating practices are used. Section 3.2.2.1 describes the facility information available for the generation of nationwide estimates.

In addition to facility-specific data, emitting characteristics of the waste management units are needed to estimate nationwide emissions. Typically, emission measurements are made at the source and those measurements serve as the basis for characterization of similar emission sources. In the case of TSDF, there is a diversity of sources and factors within a source that have a significant impact on emissions, waste composition being a major one; this variation makes estimation of nationwide TSDF emissions directly from only measured data impractical. Other factors that restrict this approach include the overall lack of emission test data for the range of TSDF management processes and the absence of standardized test methods that allow meaningful comparisons of available emission data to be made. As an alternative, emission models have been adapted to facilitate generation of waste management process emission estimates. These emission models are presented in Appendix C, Section C.1. To use the emission models, it is necessary to define certain waste management unit design and operating characteristics (such as surface area and waste retention time for surface impoundments). Given that this level of detail is not available for most facilities, process parameters based on model management units were developed for use in calculating emissions (also, costs of control and emission reductions). Using survey results and information from other sources such as design manuals and site visit reports, model units were developed in terms of operating and design parameters spanning typical ranges of surface area, retention times, and other characteristics representative of the TSDF industry. A sensitivity analysis was conducted for each model to determine which input parameters, over what range, have significant effects on emission model estimates. Appendix C, Section C.2, discusses the sources of information and rationale used to develop the TSDF model units and lists the specific characteristics of each model waste management unit that are needed to compute emissions using the appropriate emission model.

The other key element in estimating emissions is the composition of the waste in the waste management unit. The specific chemicals found in each waste management unit nationwide are not known, but data are available on waste composition from a number of facilities in several industrial categories. These data have been combined into a data base that gives

waste composition as a function of SIC and RCRA waste codes. The file is described briefly in Section 3.2.2.2 and described in detail in Appendix D, Section D.2.2.

Table 3-4 presents the relative emissions predicted by the emission models for selected model waste management units. This table lists predicted uncontrolled organic emissions by model unit for five different model waste compositions. The specific compositions of the five model wastes are given in Appendix C, Section C.2.2, along with the rationale for their development. The results in Table 3-4 illustrate the variability in emissions that may occur from waste management units for different waste compositions. The table also shows emission variability between waste management units for the same waste type. No conclusions should be drawn from this latter comparison without considering the differences in waste throughput between the waste management units. It should be pointed out that, to the extent possible, the composition and quantities of the actual waste streams processed at the existing facilities were used in estimating nationwide emissions. The model wastes are presented here to illustrate the variability in potential air emissions in relation to waste composition and management process.

In calculating nationwide TSDF air emissions, emission models are used with the model waste management unit design and operating characteristics to produce emission factors for the model units. The model unit emission factors are estimates of the fraction of specific organic compounds entering the waste management unit that become air emissions from that unit. Derivation of these emission factors involves combining the steps discussed previously in this section with a knowledge of the properties of the compounds for which emission factors are required. The development of emission factors is explained in detail in Appendix D, Section D.2.4.

3.2.2 Nationwide TSDF Emissions

Nationwide organic emissions from the TSDF industry were estimated using the Source Assessment Model (SAM), a computerized simulation program designed to generate nationwide emissions estimates on a facility, waste management unit, or emission source basis. Summation of individual facility results provides the nationwide emission estimate. The SAM utilizes a

TABLE 3-4. SUMMARY OF SELECTED MODEL HAZARDOUS WASTE MANAGEMENT UNIT
UNCONTROLLED ORGANIC EMISSION ESTIMATES FOR MODEL WASTES (Mg/yr)[a]

Model unit[b]	Model waste type				
	Aqueous sludge/ slurry	Dilute aqueous	Organic liquid	Organic sludge/ slurry	Two-phase aqueous/ organic
Covered storage tank (S02D)	0.117	2.12	0.437	1.11	0.891
Covered quiescent treatment tank (T01E)	0.24	4.6	1.19	1.40	1.94
Quiescent uncovered storage tank (S02I)	24	8.1	514	586	9.7
Quiescent uncovered treatment tank (T01B)	34	19	954	1,026	31
Quiescent storage impoundment (S04C)	686	159	--	--	183
Quiescent treatment impoundment (T02D)	946	269	--	--	326
Quiescent disposal impoundment (D83A)	842	130	--	--	16,000
Uncovered aerated/ agitated treatment tank (T01G)	870	130	--	--	--
Aerated/agitated treatment impoundment (T02J)	1,920	390	--	--	380
Waste fixation (Fixation Pit B)	4,110	--	--	--	31,700
Drum storage (S01B)	0.0036	0.0000909	0.0236	0.0298	0.000181
Dumpster storage (S01C)	0.72	--	0.049	1.44	--
Wastepiles (S03E)	139.7	--	--	--	100

(continued)

TABLE 3-4 (continued)

Model unit[b]	Model waste type				
	Aqueous sludge/ slurry	Dilute aqueous	Organic liquid	Organic sludge/ slurry	Two-phase aqueous/ organic
Landfill-active (D80E)	358	--	--	--	299
Landfill-closed (D80H)	0.068	--	--	--	2.09
Land treatment (D81C)	269	21.6	--	--	--

-- = Indicates this model unit does not manage this model waste type, thus an uncontrolled emission estimate is not available.

[a]This table lists the estimated organic emissions for selected model waste management units when the listed model wastes are managed in those units. The model unit definitions are given in Appendix C, Section C.2.1. The model waste compositions are also described in Appendix C, Section C.2.2.

[b]The parenthetical listings are the model unit designations under which the model unit definitions can be found in Appendix C, Section C.2.2.

variety of information and data concerning the TSDF industry to calculate emissions. The SAM processes the information and data from a number of input files that contain TSDF-specific information (facility location, waste management processes used, and types and quantities of wastes managed), waste characterization data (approximate compositions of typical wastes), and air emission model estimates (emission factors based on characteristics of both TSDF waste management units and waste types).

Because of the complexity of the TSDF industry and the current lack of detailed information for all TSDF, it is unlikely that the SAM estimates are accurate for an individual facility. However, it is believed that the SAM emission estimates are a reasonable approximation on a nationwide basis and the TSDF modeling approach provides the best basis for analysis of options for controlling TSDF air emissions.

A brief discussion of the input data files, assembled for and used by the SAM to calculate air emissions, and the output emissions files generated by the SAM are presented in the following sections of this chapter. Figure 3-6 outlines the main SAM files and functions used in estimating nationwide emissions from the TSDF industry. The SAM, its data inputs and outputs, and the overall logic used in the model's calculations are discussed in more detail in Appendix D.

3.2.2.1 <u>SAM Input Files</u>. There are four main data files that are inputs to the SAM nationwide uncontrolled emission estimates: the Industry Profile (a file of waste management practices for each TSDF in the Nation), the waste characterization file (also referred to as the Waste Characterization Data Base), the chemical properties file, and the emission factors file. These inputs provide the information and data necessary to calculate nationwide TSDF uncontrolled emissions.

3.2.2.1.1 <u>Industry Profile</u>. The Industry Profile data base was developed to provide a list of TSDF nationwide and to describe facility-specific waste management practices in terms of the types and quantities of wastes handled and the processes utilized. Several hazardous waste industry surveys and data bases, available through EPA's Office of Solid Waste, serve as the basis of the SAM Industry Profile (see Appendix D, Section D.2.1). The information and data from each of these surveys and data bases have been adapted to fit the needs of the SAM.
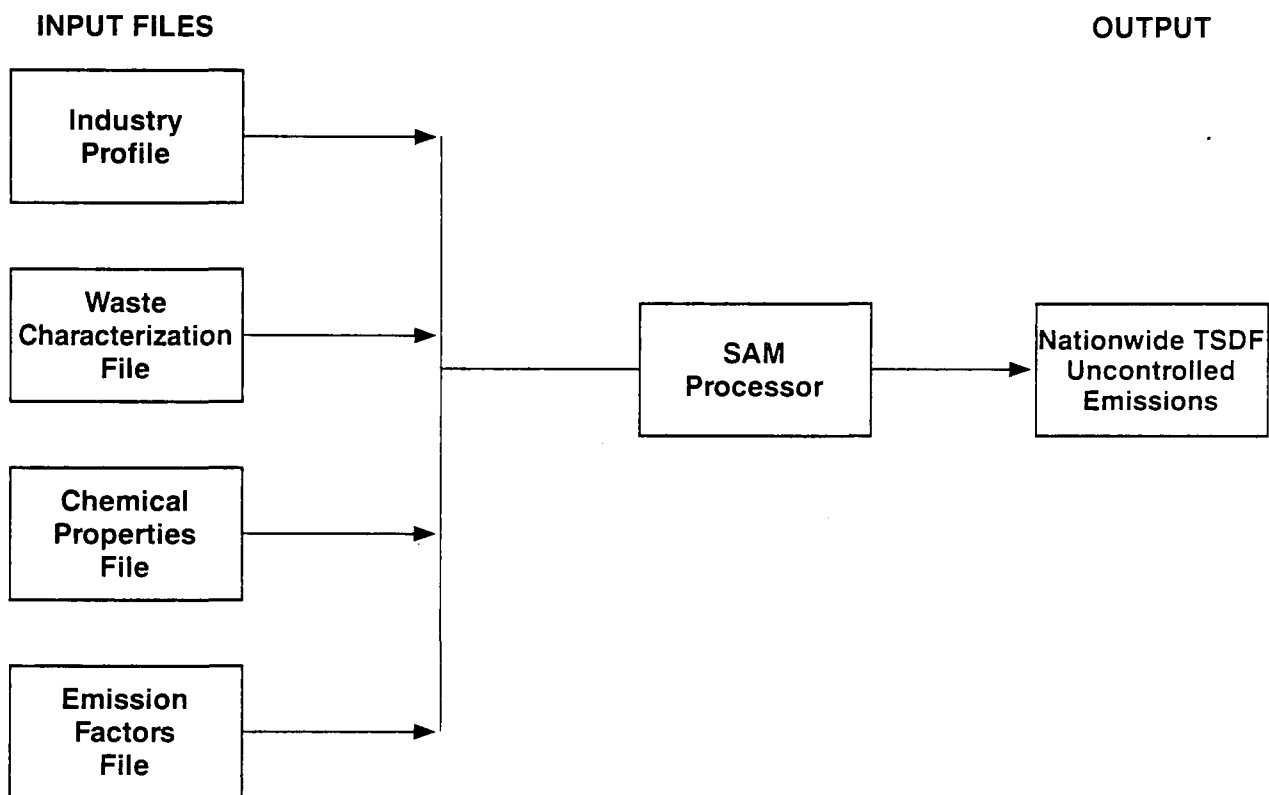
Figure 3-6. Source Assessment Model (SAM) input files used in estimating nationwide treatment, storage, and disposal facilities (TSDF) uncontrolled air emissions.

The information that the SAM uses from the Industry Profile to estimate nationwide emissions includes the following for each TSDF: (1) facility identification number (FCID), (2) location coordinates of the facility, (3) the primary SIC code for the facility, (4) the RCRA waste codes managed at the TSDF, (5) the waste quantity for each of the waste codes, and (6) the management process codes applicable to each waste code. It is important to note that the SIC and waste codes link the facility to the waste characterization file, which gives estimated waste compositions.

3.2.2.1.2 <u>Waste characterization file</u>. This waste characterization file contains waste data that have been compiled to represent chemical-specific waste compositions for each waste found within an SIC code. An RCRA waste may be generated in one of several physical/chemical forms; for example, a waste may be an aqueous liquid or an organic sludge. The waste characterization file contains the composition of waste streams in terms of chemical constituents and their respective concentrations for each physical/chemical form of a waste associated with a particular RCRA waste code in an SIC category. If specific chemical constituents were not found in the original data, chemical assignments were made based on a review of similar TSDF processes. Wherever available, specific chemicals were retained in the waste characterization file. The data provided in the waste characterization file are accessed by the SAM for each TSDF emission calculation. (See Appendix D, Section D.2.2, for a more detailed discussion.)

3.2.2.1.3 <u>Chemical properties file</u>. Emission estimation for each of the more than 4,000 waste chemical constituents identified in the waste characterization file would require property data for all compounds; many of which are not available. Therefore, to provide the emission models with appropriate constituent physical, chemical, and biological properties, the waste constituents were categorized and grouped into classes based on volatility (i.e., vapor pressure or Henry's law constant) and biodegradation. These categories were defined to represent the actual organic compounds that occur in hazardous waste streams and serve as surrogates for the particular waste constituents in terms of physical, chemical, and biological properties in the emission calculations carried

out by the SAM. (See Appendix D, Section D.2.3, for a more detailed discussion.)

3.2.2.1.4 <u>Emission factors file</u>. For each waste management process (e.g., aerated surface impoundment or treatment tank), the respective emission models applicable to the process were used to determine the amount or fraction of the organic compound entering the unit that is emitted to the air and the fraction that is biodegraded. The calculations were made for each chemical surrogate category for each waste management process. In addition to emission factors for process-related emissions, emission factors developed for transfer and handling-related emissions were also incorporated into the SAM program file. The emission factors used for estimating TSDF emissions in this document were calculated using the TSDF air emission models as presented in the March 1987 draft of the <u>Hazardous Waste Treatment, Storage, and Disposal Facilities: Air Emission Models</u>, Draft Report.[16] 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).[17] 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.[18] 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. (Appendix D, Section D.2.4, contains a more extensive discussion of emission factors.)

3.2.2.2 <u>Uncontrolled Nationwide Emissions</u>. The SAM computes nationwide uncontrolled TSDF emissions by first identifying particular waste management process units within the facility from the Industry Profile. Once a management process is identified, the SAM then calculates emissions on a chemical-by-chemical basis. The quantity of a particular chemical in the waste stream is multiplied by the appropriate emission factor, which is determined by the chemical, physical, and biological properties of the

chemical. Emissions for the unit are the sum of the emissions for each chemical constituent in the waste stream. Emissions for each management process unit can then be summed; emissions from source categories (management units with similar emission characteristics, e.g., quiescent storage impoundments and quiescent treatment impoundments) are then summed to yield a nationwide emission estimate.

The nationwide emission estimates for the current TSDF community are based on 1985 data containing general operating conditions and practices, the time covered by the most recent TSDF industry survey. These emission estimates are considered to represent the uncontrolled situation or case; review of the existing applicable State regulations has shown a wide variation in level of control required for these sources, with many States having no control requirements for TSDF.

The uncontrolled nationwide TSDF emission estimate as determined by the SAM is 1.8 million Mg of organic emissions annually. The breakdown of nationwide emissions by source category is provided in Table 3-5. (Chapter 6.0 presents additional information on these uncontrolled emissions.) Table 3-5 shows that storage tanks are estimated to be the single largest emitting source nationwide. Treatment tanks and impoundments that are aerated to promote biological activity are the second highest single source. These two source categories combined account for about 70 percent of the annual emissions estimated.

TABLE 3-5. NATIONWIDE UNCONTROLLED TSDF ORGANIC EMISSION ESTIMATES[a]

Source category	Nationwide uncontrolled emissions, 10^3 Mg/yr
Drum storage	0.19
Dumpster storage	78
Storage tanks	756
Quiescent surface impoundments[b]	209
Quiescent treatment tanks	48
Aerated/agitated tank and surface impoundments	515
Wastepiles	0.13
Landfills	40
Waste fixation	2.1
Incineration[c]	0.89
Land treatment	73
Other treatment[d]	d
Spills	0.43
Loading	6.8
Equipment leaks	80
Total	1,810

TSDF = Treatment, storage, and disposal facility.

[a]This table presents the nationwide estimates of uncontrolled TSDF organic emissions generated by the Source Assessment Model described in Appendix D. Emissions are presented for management processes that have similar emission characteristics, i.e., source categories.

[b]Includes quiescent surface impoundments used for both storage, treatment, or disposal.

[c]Uncontrolled incinerator emissions includes emissions from wastes that are routinely incinerated with stack exhaust gas emission controls. These sources are currently regulated under 40 CFR 264 Subpart O. The uncontrolled emission scenario does not include wastes that are or would be incinerated as a result of implementing the RCRA land disposal restrictions (LDR). The baseline and two example control strategies do, however, account for the incinerator emissions resulting from the LDR. The emission scenarios are explained in Chapter 5.0.

[d]Other treatment includes processes such as stream stripping that are typically used to remove organics from wastes. For the uncontrolled emission case, these emissions are built into the tank treatment category due to similarities in emission characteristics.

3.3 REFERENCES

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3. U.S. Environmental Protection Agency. The Hazardous Waste System. Office of Solid Waste and Emergency Response. Washington, DC. June 1987. p. 1-4.

4. Westat, Inc. National Survey of Hazardous Waste Generators and Treatment, Storage and Disposal Facilities Regulated Under RCRA in 1981. Prepared for the U.S. Environmental Protection Agency, Office of Solid Waste. April 1984. p. 141.

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6. Reference 3, p. 2-3.

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8. Abt Associates, Inc. National Small Quantity Hazardous Waste Generators Survey. Prepared for the U.S. Environmental Protection Agency, Office of Solid Waste. Washington, DC. February 1985. p. 2.

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10. Reference 4, p. 69.

11. Reference 2, p. 4.

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15. Reference 13.

16. Research Triangle Institute. Hazardous Waste Treatment, Storage and Disposal Facilities: Air Emission Models, Draft Report. Prepared for U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Research Triangle Park, NC. March 13, 1987.

17. U.S. Environmental Protection Agency. Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF)--Air Emission Models. Research Triangle Park, NC. Publication No. EPA-450/3-87-026. December 1987.

18. Memorandum from Coy, David, RTI, to Docket. December 18, 1987. Comparison of weighted average emission factors.

4.0 CONTROL TECHNOLOGIES

This chapter identifies and describes technologies for reducing organic air emissions from hazardous waste treatment, storage, and disposal facilities (TSDF) for the protection of human health and the environment. For each control technique identified, applicable wastes and waste management processes are identified as are the estimated levels of control that can be achieved by each technique in each application. Cross-media and secondary environmental impacts associated with the use of a control technique also are identified.

There are several general types of controls for reducing organic air emissions, including organic removal and hazardous waste incineration, emission suppression by capture or containment, the use of add-on emission control devices, and process modifications and improved work practices. Table 4-1 lists these types of emission controls and presents several emission reduction options that correspond to each control type. If organics are removed from either the waste stream prior to disposal or from an effluent stream, they must be managed appropriately to prevent air emissions or other adverse environmental impacts. It should also be noted that emission suppression does not necessarily result in a reduction in overall emissions. Unless emission suppression procedures are used in conjunction with organic removal or incineration processes, suppression may serve only to shift emissions downstream in a waste management process or to spread emissions over a longer period of time. Used alone, emission suppression is less desirable than alternatives that remove or incinerate organics.

The controls described in this chapter were considered in the development of control strategies (combinations of controls and TSDF emission sources) for TSDF air emissions. The emission reduction potential of each

TABLE 4-1. POTENTIAL ORGANIC AIR EMISSION REDUCTION
OPTIONS FOR TSDF SOURCES

Emission control type	Emission reduction options
1. Suppression controls	a. Enclosures b. Covers
2. Add-on emission control devices	a. Carbon adsorption b. Combustion of organic vapors c. Condensation
3. Organic removal/ hazardous waste incineration	a. Steam stripping b. Air stripping c. Thin-film evaporation d. Batch distillation e. Dewatering[a] f. Waste stream incineration
4. Process modification/ improved work practices	a. Coking[a] of petroleum refinery wastes[b] b. Submerged loading c. Subsurface injection[a] d. Daily earth covers e. Mechanical mixers f. Improved housekeeping g. Leak detection and repair to reduce waste transfer fugitive emissions

TSDF = Treatment, storage, and disposal facilities.

[a]Although this technique is considered to be a potential control option, the emission reduction that may result from its use has not been documented adequately.

[b]Coking of petroleum refinery wastes has not been considered as a control option because petroleum refinery waste is expected to be regulated by the land disposal restrictions. (For further explanation, refer to Chapter 5.0, Section 5.3.2.1.)

control was evaluated and, where possible, a control efficiency was assigned for use in estimating the nationwide impacts of applying various strategies. For some of the potential controls discussed in this chapter, emission reductions could not be documented; therefore, they were not explicitly used in the formulation of control strategies and in the estimation of nationwide impacts of control strategies.

A summary of the controls used in the development of control strategies is presented in Section 4.9, following the discussion of potential controls in Sections 4.1 through 4.7. Cross-media impacts created from these controls are addressed in Section 4.8. Discussion of control strategies is presented in Chapter 5.0, and the health and environmental impacts of example control strategies are presented in Chapter 6.0. Chapter 7.0 presents the cost impacts of the example control strategies. The model developed to estimate nationwide impacts of control strategies (referred to as the Source Assessment Model) is described in Appendix D.

4.1 SUPPRESSION CONTROLS

Suppression controls reduce emissions by containing the organics within a confined area and preventing further vaporization. Unless used in conjunction with an add-on control device such as a carbon adsorption unit, these controls may shift the emissions further downstream in the waste management process or spread the emissions over a longer period of time.

4.1.1 Enclosures

4.1.1.1 Air-Supported Structures. An air-supported structure is an anchored, flexible membrane dome that is supported by maintaining a positive pressure under the dome relative to the surrounding atmosphere. The dome requires a tightly sealed anchoring system so that the positive pressure can be maintained. Anchoring typically involves attaching the structure to a concrete footing around the perimeter of the dome. A large fan, drawing some outside air, provides the necessary pressure differential, usually about 10.1 kPa (0.1 atm), between the inside and outside of the structure. In addition, an exhaust vent and an airlock entrance are provided for air removal/collection and access, respectively. The exhaust vent allows installation of a pollutant control system, such as a carbon adsorption unit. An air-supported structure is illustrated in Figure 4-1.

VINYL-COATED
POLYESTER BASE
FABRIC

BIAS HARNESS
NET SYSTEM

INFLATION/HEATING
SYSTEM

VEHICULAR
AIR-LOCK

PERSONNEL DOOR
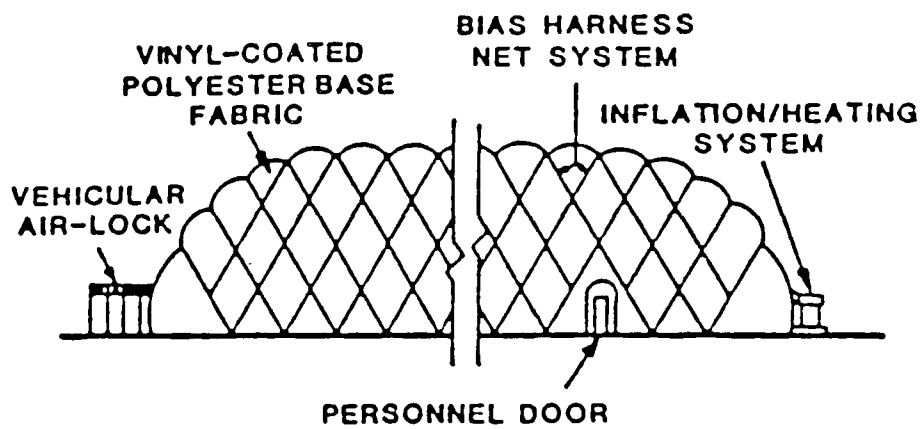
Source: Air Structures International, Inc.

Figure 4-1. Typical air-supported structure.[1]

Complete enclosure by an air-supported structure is feasible if vapor collection and disposal methods that minimize air emissions are employed, if the dome materials are compatible with the vapors, and if the dome is built to withstand the local weather. If high humidity levels are expected inside the structure and carbon adsorption is used for emission control, it is important that the system design take into account the tendency of moisture to reduce the adsorptive capacity of carbon beds (see Section 4.2.2). Air-supported structures can be built to cover large areas and have been designed to cover areas of 4 acres and greater.[2,3] They are appropriate for hazardous waste management processes that are compatible with the limited access available through the airlock entranceways and with reduced sunlight and wind. Treatment and storage impoundments and landfills are the waste management processes that are most appropriately controlled by air-supported structures.

Air-supported structures have been designed and built for both impoundments and landfills. There is one documented installation of an air-supported structure for odor control.[4] Vendors of air-supported structures have indicated the existence of several installations for emission control.[5] Although other waste management processes such as wastepiles and other storage units could be controlled by enclosures, no known installations had been built as of 1986. In some cases, enclosures could be used to control multiple management processes, but the physical problem of access could limit such applications.

The efficiency of air-supported structures in reducing or suppressing emissions is determined by (1) the reduction in wind- or sunlight-induced volatilization of organics, and (2) the combined effects of the capture efficiency of the structure and the removal efficiency of the control device in removing organics. An enclosure alone may not reduce emissions, but because it allows venting of the exhaust air to a control device, high theoretical emission reductions are achievable. However, tests at one facility showed that actual control efficiencies were less than theoretical or predicted levels due to adverse moisture effects on the carbon adsorber control device.[6] Factors that affect control efficiency include preventing air loss through sources other than the vent (e.g., seals, doors, ducting)

and the efficiency of the control device in removing organics from the exhaust stream. Because air-supported structures enclose the entire area of the emission source, the efficiency of the enclosure in capturing emissions should be essentially 100 percent. Thus, the overall control efficiency of an air-supported structure vented to a control device will be equivalent to the efficiency of the control device.

Air-supported structures could be vented to several types of control devices such as thermal or catalytic incinerators and carbon adsorption systems. These alternative devices are discussed in Section 4.2. The selection of the control device is dependent on exhaust air flow rate, concentration of organics in the exhaust air, and the specific organic pollutants present. Carbon adsorbers were selected for use in generating estimates of nationwide controlled emissions and costs for vented air-supported structures on the basis of comparative model unit costs. However, the specific site conditions at a TSDF might cause an alternative device with equivalent performance, such as a vapor incinerator, to be less costly. For the purpose of estimating nationwide emissions, an overall control efficiency of 95 percent is used for air-supported structures vented to a carbon adsorber, which is based on the control efficiency of carbon adsorption as discussed in Section 4.2.1. (See Appendix F, Section F.1.2.2, for a discussion of an air-supported structure.)

An air-supported structure that is vented to a carbon adsorber has associated cross-media and secondary environmental impacts. Carbon adsorbers generate cross-media impacts in the form of spent carbon and if regenerable carbon beds are used, effluent streams of condensed steam and organics are generated. Regenerable carbon adsorption also has associated secondary environmental impacts in the form of air emissions from the combustion of fuel to produce steam used in the regeneration process.

4.1.1.2 <u>Rigid Structures</u>. "Rigid structures" refers to permanent buildings designed to contain emissions from stored waste or waste processing operations. Rigid structures can be used to control waste storage or waste processing emissions. Typically, they would be used to enclose drum storage or drummed waste fixation areas, wastepiles, and pits or mechanical mixers for fixation of the bulk liquids and sludge wastes normally handled

at TSDF. The designs of these structures are variable and highly site-specific. Although all-metal structures frequently are used, other types of construction undoubtedly would be suitable for some applications.

The buildings themselves, without added emission control devices, serve to limit organic emissions by reducing the windspeed across the surfaces of exposed wastes within the structure. Emissions are further reduced if building air is evacuated to an emission control device. Evacuation imposes a slight negative pressure on the building, thereby minimizing the loss of airborne emissions through openings in the structure.

Three operations at TSDF were identified as having metal buildings that were designed and installed to limit the escape of emissions to the atmosphere. Two of these enclose waste fixation pits,[7,8] and the third encloses pugmills (used for waste fixation) and two wastepiles.[9] All three of these buildings are evacuated to scrubber systems designed for both particulate and odor control.

No data on the emission reduction achievable by either nonevacuated or evacuated buildings were found in the literature. However, if the buildings are evacuated at a rate sufficient to maintain negative pressure at the enclosure doors, capture efficiency should approach 100 percent, and overall emission reductions will be equal to the efficiency of the control device.

Rigid structures may be vented to a variety of control devices depending on the types of pollutants (organics, particulates) in the exhaust air. Section 4.2 describes some of the control devices for organic emission control. As in the case of air-supported structures, carbon adsorption and thermal or catalytic incineration are candidates. The choice among these would depend on site-specific factors such as exhaust air flow rate, organic concentrations in the exhaust air, and the specific compounds present.

In generating nationwide estimates of controlled emissions and costs, rigid structures were assumed to be present at TSDF where drum storage is practiced. This is a reasonable assumption because good operating practice would lead to isolation of the stored drums from wind, rain, and other

environmental factors that might adversely affect the containers. Also, the rigid structures were assumed to be vented to carbon adsorption systems, with a control efficiency of 95 percent, as discussed in Section 4.2.1. Carbon adsorption was selected, as opposed to incineration, because of the relatively low organic concentrations in the exhaust air. Organic emissions are likely to be caused mostly by opening drums for inspection or by spills, both of which are intermittent.

Cross-media and secondary environmental impacts associated with the installation of rigid structures are all directly attributable to the emission control devices used to clean the exhaust air. Where scrubbers are used, contaminated blowdown water is generated. If a baghouse or carbon adsorption unit is installed, provision must be made for disposing of the baghouse dust or spent carbon. With regenerable carbon adsorbers, spent carbon must be disposed of and contaminated steam and organic condensate must be dealt with. Carbon regeneration also results in secondary air emissions produced by the combustion of fuel to generate steam used for regeneration.

4.1.1.3 Pressurized Tanks. Pressurized tanks are used in the chemicals manufacturing industries to store volatile organic liquids. The extent to which they are used in TSDF is unknown. Given that some wastes managed in TSDF are similarly volatile, it is reasonable to assume that pressurized tanks could be used as a suppression-type control device in TSDF.

A pressurized tank operates at pressures greater than atmospheric and is equipped with a pressure relief valve to prevent excessive pressure buildup. The two general classes of pressurized tanks are low pressure (120 to 200 kPa [1.2 to 2.0 atm]) and high pressure (greater than 200 kPa [2.0 atm)].

Pressurized tanks generally are used for storage of organic liquids with high vapor pressures, and they vary in size and shape depending on the operating pressure of the tank. Under routine loading, unloading, and storage operations, a high-pressure tank can be considered to be a closed system with no estimated organic emissions. In low-pressure tanks, working emissions may occur during tank filling when internal vapor pressure

exceeds the maximum relief operating pressure. Low-pressure tanks can be considered a control alternative for small (less than 76 m^3) fixed-roof tanks that store all types of waste. The emission reduction achieved depends on the setting of the pressure-relief valve and the vapor pressure and temperature of the stored material. For a pressure-relief valve setting of 200 kPa (2.0 atm), reported emission reductions range from 71 to 100 percent; for a setting of 120 kPa (1.2 atm), reported reductions range from 22 to 45 percent.[10] Pressurized tanks are one of many options available for controlling tank emissions. However, they are regarded as generally more expensive than other control options for tanks that can achieve similar emission reductions. Therefore, in estimating nationwide emissions, other control options were used instead of pressurized tanks; however, pressurized tanks may be a viable option under some conditions. No cross-media or secondary environmental impacts are associated with the use of pressurized tanks.

4.1.2 Covers

Three basic types of covers are used for storage vessels containing aqueous and/or organic liquids: fixed roofs, external floating roofs, and internal floating roofs. Both the external and internal floating roofs employ a platform that sits (floats) on the surface of the stored liquid. Figure 4-2 shows an example of each storage vessel cover type. Other cover types include floating synthetic membranes and flexible covers. There are no cross-media or secondary environmental impacts associated with the use of covers.

4.1.2.1 Fixed Roof. Fixed-roof tanks are widely used in TSDF to store liquid wastes containing organics with a wide range of volatilities. The extent to which fixed-roof tanks are used for waste treatment is not known. Those treatment processes requiring infrequent access to the tank surface or personnel access or not requiring large clearances between the liquid surface and a roof for operating equipment are amenable to placement in fixed-roof tanks.

A permanently affixed roof for a tank vessel is a rigid structure that typically is equipped with a pressure/vacuum vent. This allows the tank to be operated at a slight pressure differential with respect to the outside in order to control emissions. The roof also may contain access ports such
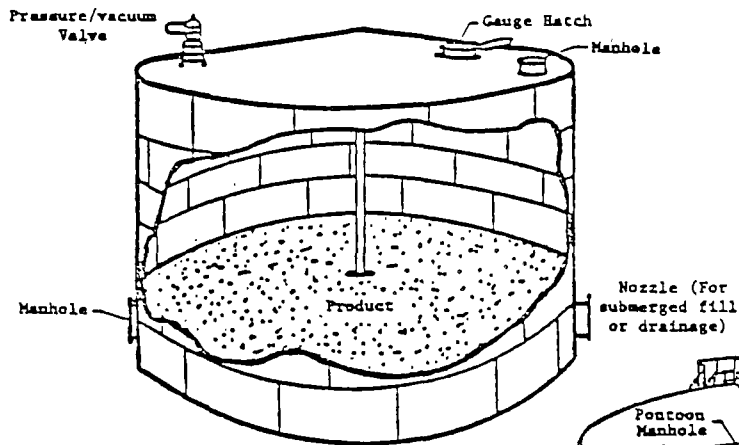
Typical fixed roof tank.
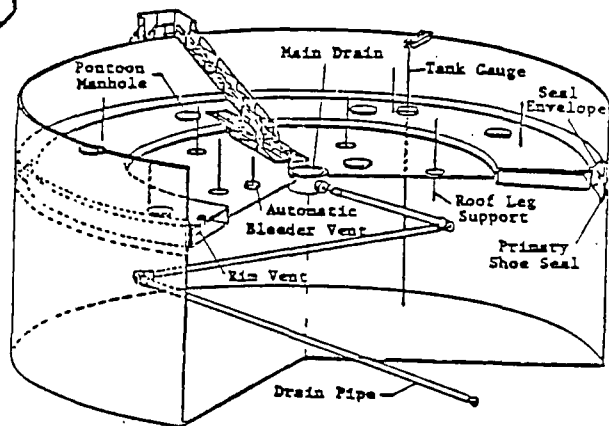
External floating roof tank.
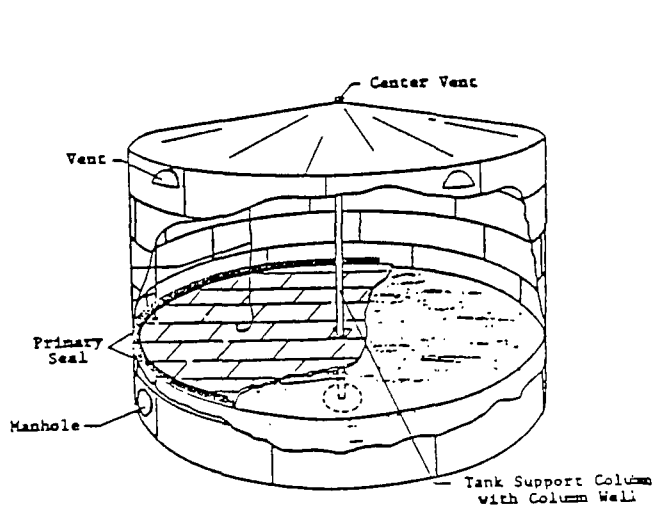
Contact Deck Type
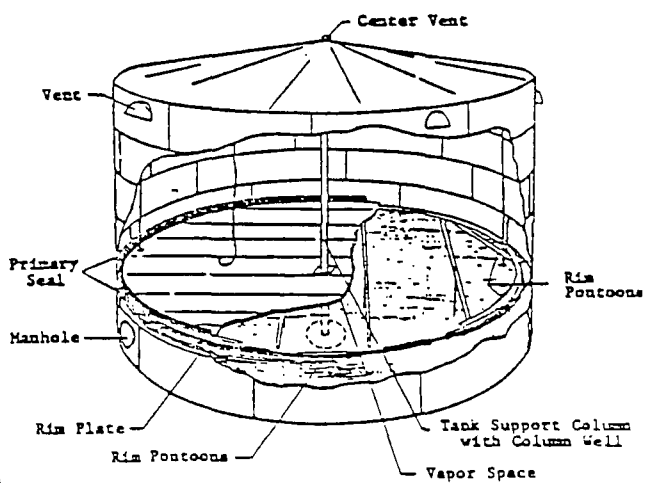
Noncontact Deck Type

Internal floating roof tanks.

Figure 4-2. Storage tank covers.

as a manhole and a gauge hatch. Roof shapes vary from flat to dome or cone shaped. Roof shape may be an important consideration for some applications. For example, a high dome-shaped roof may be needed to cover a tank with a surface-mounted aerator. Emissions from fixed-roof tanks may be caused by leaks, breathing losses, or working losses. A fixed-roof tank may leak due to the seals at the valve, hatch, and manhole. Breathing losses, caused by vapor expansion and contraction, are the result of changes in temperature and barometric pressure. Losses due to filling and emptying are called working losses. As the liquid level changes, the vapor space either is forced out or draws in fresh air that then becomes saturated and expands, forcing air out of the tank.

The emission models described in Appendix C, Section C.1.1.1.1 (emissions from uncovered [open-top] tanks) and Section C.1.1.3.2 (fixed-roof tank emissions) were used to estimate emission reductions for fixed roofs applied to uncovered tanks. The tank design parameters used to estimate emission reductions are described in Section C.2.1.1. (Refer to model unit S02I [uncovered storage tank] and T01B [uncovered, quiescent treatment tank].) Waste compositions used to estimate emission reductions included five model wastes listed in Table C-5, excluding the organic-containing solid waste and dilute aqueous-2 and -3 wastes. In addition, two alternates to each of the five Table C-5 model waste compositions were used to estimate emission reductions. These two alternate waste compositions contain the same organic compounds, but at different concentrations than those listed in Table C-5. The average of the three emission reductions for each waste form was computed.[11,12] Under these conditions, the emission reductions for fixed roofs applied to uncovered tanks ranged from 86.4 to 99.2 percent, depending on waste form (e.g., dilute aqueous or organic sludge/slurry). The stated range includes both storage and treatment tanks. The differences between storage and treatment tank emission reductions for a given waste form were small (less than 3.5 percent). The range in emission reductions is attributable to the variations in organic compounds present in the model wastes and their concentrations.

On the basis of the above analysis, nationwide emission estimates were made using emission reductions of 86 to 99 percent for a fixed roof applied to an uncovered (open-top) tank.[13]

4.1.2.2 Internal Floating Roof. Fixed-roof tanks with internal floating roofs are used in the petroleum refining industry to store liquids containing volatile organic compounds. The extent to which they are used in TSDF for managing the refining or other industry wastes is unknown. Providing there are no waste components incompatible with internal floating roof materials of construction, it is reasonable to assume that internal floating roofs could be applied to fixed-roof storage tanks to suppress organic emissions from certain types of wastes.

An internal floating roof is an aluminum or steel floating structure, called a deck, that controls the escape of vapors from within fixed-roof tanks. The fixed-roof tank has vents that may allow volatile organics to be released during filling. In tanks with internal floating roofs, the deck rises and falls with the liquid level and either floats directly on the liquid surface (contact deck) or rests on pontoons several inches above the liquid surface (noncontact deck).[14] Rim seals slide up and down the tank wall as the deck moves with the liquid. Fixed-roof tanks that have been retrofitted to employ an internal floating deck typically are fitted with vertical columns inside to support the roof.[15] The deck restricts evaporation of organics by maintaining a constant volume of space between the liquid surface and the deck. Some emissions still occur through deck fittings, nonwelded deck seams, and the space between deck and wall.

Installation of internal floating roofs are appropriate for storage tanks or quiescent treatment tanks in which the tank contents and the deck seal are compatible. Most liquid and aqueous wastes can be stored in tanks equipped with internal floating roofs, but corrosive wastes may not be compatible with deck seals. Internal floating roofs are well-tested in industrial settings.[16]

The effectiveness of internal floating roofs in reducing emissions relative to a fixed-roof tank is a strong function of tank size, annual turnovers, and vapor pressure of the stored liquid. In addition, the type of roof and seal system employed in the floating roof also affects the emission reductions achievable with internal floating roofs. One analysis using a model tank having 50 turnovers per year and storing volatile organic liquids showed emission reductions of 93.4 to 97.3 percent, depending on roof and seal type, relative to a fixed-roof tank.[17]

Emission reductions were also estimated by using the emission models described in Appendix C, Section C.1.1.4.2 (fixed-roof tank emissions) and Reference 18 (emissions from tanks with internal floating roofs). The tank design parameters used in this analysis are those described in Section C.2.1.1, for model unit S02I. Waste compositions assumed are those model wastes listed in Table C-5, excluding the organic-containing solid and dilute aqueous-2 and -3. Under these conditions, the estimated emission reductions ranged from 74 to 82 percent.[19,20] The range in estimated emission reductions is attributable to the variations in compositions and concentrations of the model wastes by waste form, e.g., dilute aqueous vs. organic sludge. Emission reductions estimated using emission models and model wastes described in Appendix C are less than those in the first referenced analysis due to the model wastes having different vapor pressures and the tank sizes and throughputs being different.[21] The model waste compositions and model unit design parameters provide a better representation of the spectrum of operating conditions for TSDF than the first referenced analysis. For the purpose of estimating nationwide emissions, calculated emission reductions ranging from 74 to 82 percent, depending on waste form, are used as the control efficiency for internal floating roofs when placed inside a fixed-roof tank.

Internal floating roofs may also be applied to an open-top vertical tank 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 applications of the fixed roof to the uncovered tank, plus application of an internal floating roof to a fixed-roof tank. The range of emission reductions achievable based on combinations of the fixed roof with an internal floating roof is 96 to 99 percent. This range of emission reductions, depending on waste form, is used to estimate nationwide emissions from uncovered tanks after applying an internal floating roof in combination with a fixed roof. An alternative to this combination is application of an external floating roof to the uncovered tank, discussed in the next section.

4.1.2.3 <u>External Floating Roof</u>. Tanks with external floating roofs are used in the petroleum refining industry to store liquids containing

volatile organic compounds. As with internal floating roofs, the extent to which external floating roofs are used in TSDF for managing the refining or other industry wastes is unknown. Except for incompatibility of the materials of construction with the stored or treated wastes, it is reasonable to assume that an external floating roof could be applied to uncovered vertical tanks to suppress organic emissions from certain types of wastes.

The external floating roof is similar to an internal floating roof, except there is no permanent fixed roof on the top of the storage tank. The deck rises and falls with the surface of the liquid. The space between the deck and the vessel wall is controlled by a seal or seal system. The effectiveness for controlling organic losses is determined by the ability of the seal to fill the spaces between deck and wall. One analysis using a model tank having 50 turnovers per year showed emission reductions ranging from 26 to 99 percent depending on seal type, relative to a fixed-roof tank.[22]

In developing cost and application data for applying external floating roofs to open-top tanks, equipment vendors and consultants were contacted. Two vendors indicated that external floating roofs were generally not applied to tanks of less than 9 meters (30 feet) diameter.[23,24] An engineering consultant indicated that maintenance costs for the external floating roofs were higher than for internal floating roofs.[25] This consultant suggested that the additional capital cost for an internal floating roof combined with a fixed roof could be recovered in 3 to 5 years in reduced maintenance costs as compared to the external floating roof.

The TSDF statistics used to derive the model unit definitions as described in Appendix C, Section C.2.1, suggest that the TSDF storage and treatment tanks typically tend to be smaller in diameter than 9 meters. In fact, only the largest defined model tank units are about 9 meters in diameter; the others are smaller. This fact, when combined with the vendor comment indicating relatively high maintenance costs offsetting lower capital costs for external floating roofs, leads to the selection of internal floating roofs in combination with a fixed roof as the preferred type of floating roof for national controlled emissions and control cost estimates. This does not mean that external floating roofs are not a good

choice. For certain site-specific conditions, an external floating roof may be a better choice than the combination of internal floating roof combined with a fixed roof.

4.1.2.4 Floating Synthetic Membrane. Floating membranes are applicable to quiescent impoundments and uncovered storage tanks including concrete-lined impoundments, which are defined as storage tanks. They have been used to cover potable water supplies since the early 1970's and have been used at Superfund sites to restrict inflow of rainwater.[26] They also have been used as odor-control devices for surface impoundments.[27]

Floating synthetic membranes are covers that float on aqueous/liquid surfaces; they must be made of materials that are (1) chemically resistant, (2) temperature- and weather-resistant, (3) relatively impermeable to gases and vapors, and (4) physically resistant to tearing and stretching. They are designed to float directly on a liquid surface or on pontoons. Pontoon systems are designed as gas collection systems that vent off-gases to a control device.[28] A floating synthetic membrane that floats directly on the liquid surface will not, for the most part, allow gases and vapors to form under the membrane. Floating membranes are manufactured with cables for anchoring; concrete or dirt footings are used to keep the membrane in place.[29] Except under the most arid conditions, a rainwater collection system must be used to remove water that collects on top of the membrane.[30]

Emission reductions greater than 90 percent can be expected for compatible liner-aqueous waste systems.[31] Emission reductions are determined by the fraction of surface area covered or, in the case of a pontoon system, by the control efficiency of gas collection and removal systems, if in place, and by the permeability of the membrane.

One synthetic membrane vendor reports that if the membrane floats directly on the liquid surface and the membrane perimeter is completely sealed to prevent entrance or exit of air, the only organic loss mechanism is permeation through the liner.[32] However, the vendor also reports that complete sealing at the perimeter is not typical for reasons such as liquid level changes in the impoundments. Under the condition that a portion of the impoundment surface area is uncovered, the losses due to permeation are much smaller than losses from the uncovered surface.

An analytical approach was taken to estimate emission reductions for floating synthetic membranes in the absence of measured data. Computations were made for the three model unit impoundment surface areas (model units are defined in Appendix C, Section C.2.1.1) using a wall slope of 3:1 (horizontal to vertical) and assumed liquid level changes that would leave a portion of the liquid surface uncovered.[33] This analysis was used to select 85 percent as the emission reduction basis for floating synthetic membranes for purposes of estimating nationwide emissions from membrane covered impoundments.

4.1.2.5 <u>Flexible Covers</u>. Flexible covers are synthetic membranes used to suppress or limit emissions from area organic emission sources. A typical cover material is 30-mil high-density polyethylene (HDPE). This material is readily available and easily seamed to form sheets large enough to cover any area desired (HDPE currently is used in landfill liners that occupy many acres).

Flexible covers suppress organic air emissions by imposing a vapor barrier between the emission source and the atmosphere. They would be most applicable to landfills and to wastepiles and other temporary sources of VO emissions such as loaded open trucks or dumpsters. In addition to having suppressed air emissions, covered sources would no longer be exposed to precipitation that could otherwise infiltrate the waste and produce leachate to be collected and treated.

The emission reduction obtained with flexible membranes depends on the particular combination of organics and synthetic membrane material. In a series of laboratory experiments designed to measure the diffusion of various organic compounds through polyvinyl chloride (PVC) membranes, Thibodeaux et al.[34] found that the effectiveness of the membrane as a vapor barrier varied with the chemical being tested. The three compounds tested and their measured fluxes were:

- Methanol--0.58 $g/m^2/h$

- Methylcyclohexane--3.43 $g/m^2/h$

- 1,2-Dichloropropane--13.6 $g/m^2/h$.

These fluxes are averages of values reported in the reference. Emission reductions calculated using analytical emission models showed similar variability when used to calculate emission reductions achieved by 30-mil HDPE. Calculated reductions ranged from 0 to 99 percent for three of the model waste compositions described in Appendix C, Section C.2.2.[35] These calculations were made using Fick's law of diffusion and the diffusion and permeability characteristics of the waste constituents and liner. The wide range of emission reductions is attributable to the wide range of specific compound permeabilities and the fact that permeation occurs at a fixed rate for specific compounds. If a compound is present under the membrane in low concentration, then the apparent emission reduction, expressed as a percentage, could be low, e.g., 0 percent. If the compound is present at high concentration under the membrane, then the apparent emission reduction will be high, e.g., 99 percent. This large range of variations is likely to be typical for wastes put into landfills and wastepiles.

Reductions in organic emissions depend in part on the frequency with which the cover is removed from the waste to permit normal operations such as waste addition or removal. The state of repair of the cover and the effectiveness of the anchoring system (at the edge of the membrane where it is secured to the substrate) are other factors that could influence the organic emission reduction achieved. Synthetic membranes can also be adversely affected by sunlight and chemical attack.

For the purpose of estimating nationwide emissions, emission reductions of 0, 49.3, and 99.7 percent, for organic-containing solid, two-phase aqueous/organic (after fixation), and aqueous sludge/slurry (after fixation) model wastes, respectively, are used for 30-mil HDPE covers. These values were selected based on the above described calculations for three model waste compositions. Using the same calculation methodology, emission reductions of 0, 84.8, and 99.9 percent were selected for the same model wastes with a 100-mil HDPE cover. The emission reduction calculated for the two-phase aqueous organic model waste is also used for organic liquids and organic sludge/slurry (after fixation) model wastes. The calculated emission reduction for the aqueous sludge/slurry is used for dilute aqueous waste (after fixation).

4.2 ADD-ON EMISSION CONTROL DEVICES

Add-on emission control devices are those devices used to separate contaminants (in this case, organics) from a conveying-waste gas stream. The add-on devices discussed in this section are carbon adsorbers, condensers, and several types of combustors.

4.2.1 Generic Control Devices

Several types of add-on controls may be applied to waste gas streams and be designed to achieve similar levels of emission reductions. Given that equivalent levels of emission reduction may be achieved by the devices, the choice among the devices for any particular site will depend on site-specific factors that would tend to make one device less expensive than the others, or preferable for some other reason. Subsequent sections of this chapter will discuss the factors that will influence the choices of device for particular sites.

In analyzing the nationwide emission reductions achievable by applications of the control devices and their associated costs, it has been necessary to account for the fact that not all control devices can be applied to all sources with equal cost and equal effectiveness. Incompatibility may be a problem for certain waste compositions and certain controls, for example. As a result of this fact, the concept of generic control devices has been developed. A generic control device is the combination of specific control devices assumed to be applied to an emission source category for the purpose of estimating nationwide emissions and control costs. For example, a covered tank may be controlled by venting to any of several control devices or by equipping it with an internal floating roof. Nationwide, both may be done, so the generic control for fixed- roof tanks should be a combination of both. For purposes of estimating nationwide emissions and costs, generic control devices must be assumed to be one of the specific control devices, or some combination of one or more of those specific control devices listed.

The add-on control device bases (generic control device definitions) for estimating nationwide emission and control costs (control strategies are described in Chapter 5.0, emission impacts in Chapter 6.0, and capital

and annualized costs in Chapter 7.0) are presented in Section 4.9 of this chapter.

4.2.2 Carbon Adsorption

Gas-phase carbon adsorption is widely used to control organic emissions to the atmosphere. Carbon's activated surface sites allow organics to adhere to carbon particles as they pass through a carbon bed. When the capacity of the carbon to adsorb organic compounds is exhausted, the spent carbon is replaced or regenerated.

The two basic configurations for gas-phase carbon adsorption systems are regenerative, referred to herein as fixed-bed carbon adsorption, and nonregenerative, which is referred to as carbon canisters. In fixed-bed systems, two carbon adsorption units often are operated in parallel so that one may operate while the other is being regenerated. Regeneration of spent carbon normally is accomplished by steam stripping. In carbon canister systems, the spent carbon is replaced with fresh carbon and the spent carbon is either disposed of or regenerated for eventual reuse. Detailed descriptions of equipment and operating principles are presented in several EPA reference documents.[36,37,38] A simple carbon canister unit, a $0.21-m^3$ (55-gal) drum filled with activated carbon and equipped with an inlet and an outlet port,[39] is illustrated in Figure 4-3.

Activated carbon selectively adsorbs organic vapors from gases even in the presence of water.[41] However, if the gas stream relative humidity exceeds 50 percent, then the capacity of the carbon for organics may be diminished. Also, if the carbon is saturated with water when organic compound adsorption is begun, the effectiveness of the carbon is reduced. Solvents having low molecular weights (particularly Resource Conservation and Recovery Act [RCRA] waste code F005 solvents) are not readily recovered from air streams by activated carbon.[42] The presence of multiple organic components in the gas stream (probably typical for TSDF) may result in preferential adsorption of certain components, reducing the apparent effectiveness of the carbon bed for those components not preferentially adsorbed. If the organic constituents likely to be present in the gas stream are known in advance, the system design can be adjusted to
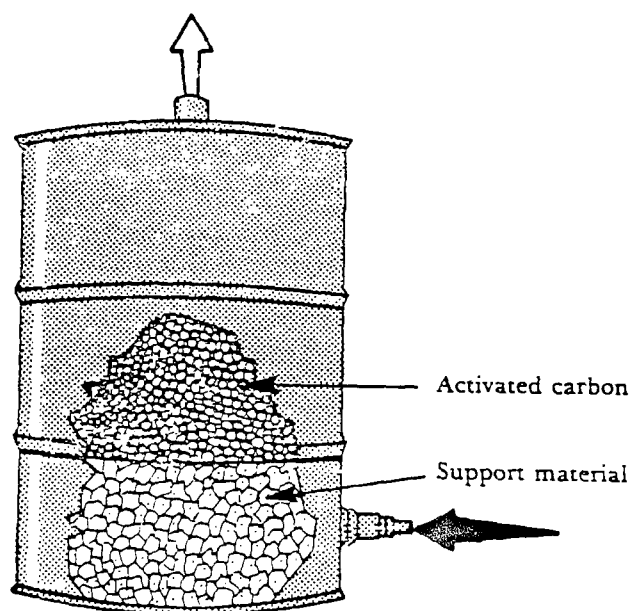
Figure 4-3. Nonregenerative carbon adsorption (carbon canister) unit.[40]

accommodate this situation. If not, the problem will result in more frequent regeneration or replacement of the carbon, thus increasing operating costs.

For safety reasons, gas streams with organic concentrations greater than 25 percent of the lower explosive limit would be precluded from treatment although dilution air could be added to reduce the concentration. Additionally, system design should consider the heat released by adsorption, which could raise the temperature of the carbon bed enough to cause spontaneous combustion.[43] If the waste gas stream contains particulates, they will tend to plug the voids in the carbon bed, rendering it ineffective. This can be avoided by filtering the gas feed stream for particulates.

Well-designed and well-operated state-of-the-art gas-phase carbon adsorption systems can reliably remove 95 percent of many types of organics contained in hazardous wastes from contaminated gas streams and are capable of achieving control efficiencies exceeding 99 percent.[44] The adsorption capacity and thus the efficiency of activated carbon are affected by:[45]

- Type of organic compounds and inlet mass loading
- Moisture content of the inlet gas
- Temperature of the inlet gas
- Carbon type, amount, and condition.

The presence of moisture in the inlet gas stream can decrease the organic adsorption capacity of the activated carbon. As a result, waste gas streams that contain entrained liquids or that have a relative humidity approaching 100 percent will need to have some of the moisture removed before the gas stream passes through the carbon bed. Entrained liquids can be removed with any one of several types of demisters, and relative humidity can be reduced by cooling and then reheating the gas stream to condense out the moisture or by raising the gas stream temperature if the temperature of the inlet stream is sufficiently low that the increase in temperature does not affect adsorption efficiency.[46] Condensate can be treated with regeneration steam condensate, as discussed later in this section.

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Background information developed by EPA to support standards for petroleum refinery wastewater systems indicate that carbon adsorption can reliably achieve emission reductions of 95 percent.[47] Because of the similarity of the sources and wastes at TSDF, equivalent emission reductions would be expected for TSDF sources. Consequently, in estimating nationwide emissions, control efficiencies of 95 percent are used for both fixed-bed carbon adsorbers and carbon canisters.

A field evaluation of carbon canisters designed to control breathing and working losses from neutralizer tanks in the wastewater treatment (WWT) system at a specialty chemicals manufacturing plant is summarized in Appendix F (Section F.2.2.1.2). In that system, the drums were achieving a high degree of removal (100 percent) 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).

There are cross-media and secondary environmental impacts associated with the use of gas-phase carbon adsorption. Organics that are not adsorbed from the gas stream will be emitted and may require secondary control such as condensation or incineration. With proper design, i.e., knowing what compounds may be present in the gas stream and designing for them, this impact should be minimized. Transfer, storage, and handling operation (TSHO) fugitive emission sources include the handling of spent carbon if it is regenerated offsite, transport operations to and from onsite regeneration facilities, and routine maintenance operations such as column cleaning or equipment repair. Organic emissions may occur during off-site regeneration without proper air pollution controls.

If a steam desorption cycle is used and the recoverable organics are soluble in water, then some form of water treatment or separation process is required for the wastewater. For example, steam stripping with condensation of the overhead product might be used, which will have associated process (e.g., the condenser and product receiver vents) and TSHO fugitive emission sources. If the organics are insoluble in water, they can be separated from the condensate by decantation. Land disposal of spent carbon constitutes a cross-media impact for this form of emission control.

Primary emissions from energy production for carbon regeneration are those associated with thermal regeneration. Such emissions include furnace or afterburner off-gases, which will usually contain the fully oxidized products of the oxidized adsorbates (e.g., HCl from a chlorinated solvent or SO_2 from a sulfur-containing material). Also, the regeneration process will produce an ash that may require further treatment. If a flue gas scrubber on the regeneration furnace is necessary, it of course will produce waste streams that may also need treatment.

4.2.3 Combustion

4.2.3.1 Thermal Incineration of Organic Vapors. Vent gases from fixed-roof storage or treatment tanks and air-supported structures covering impoundments may be candidates for thermal incineration to destroy the organic vapors. Thermal incineration is widely used for organic vapor destruction in the chemical manufacturing and metal foundry industries. The extent to which thermal incineration is currently used for vapor destruction in TSDF is unknown.

Thermal incineration of organic vapors is achieved in any device that uses a flame (temperature) combined with a chamber (time and turbulence) to convert combustible material to carbon dioxide and water. An incinerator usually consists of a refractory-lined chamber that is equipped with one or more sets of burners. The organic-laden gas stream is ducted from the emission sources to the burner zone. A flame is maintained in the burner zone by combustion of auxiliary fuel and air. The organic vapors are heated above their ignition temperature in the burner zone, then expand into one or more combustion chambers maintained at a constant temperature. The combustion products then are exhausted to the atmosphere. Heat recovery (e.g., a shell-and-tube heat exchanger for preheating inlet gas) may be used to minimize fuel consumption. Figure 4-4 illustrates a thermal incinerator. Detailed descriptions of equipment and operating principles can be found in several EPA reference documents.[48-51]

Incineration is recognized as the most universally applicable of available organic emission control methods because it can be used to destroy essentially all types of organic compounds from a variety of sources.[52] One possible limitation of an incineration system might be the
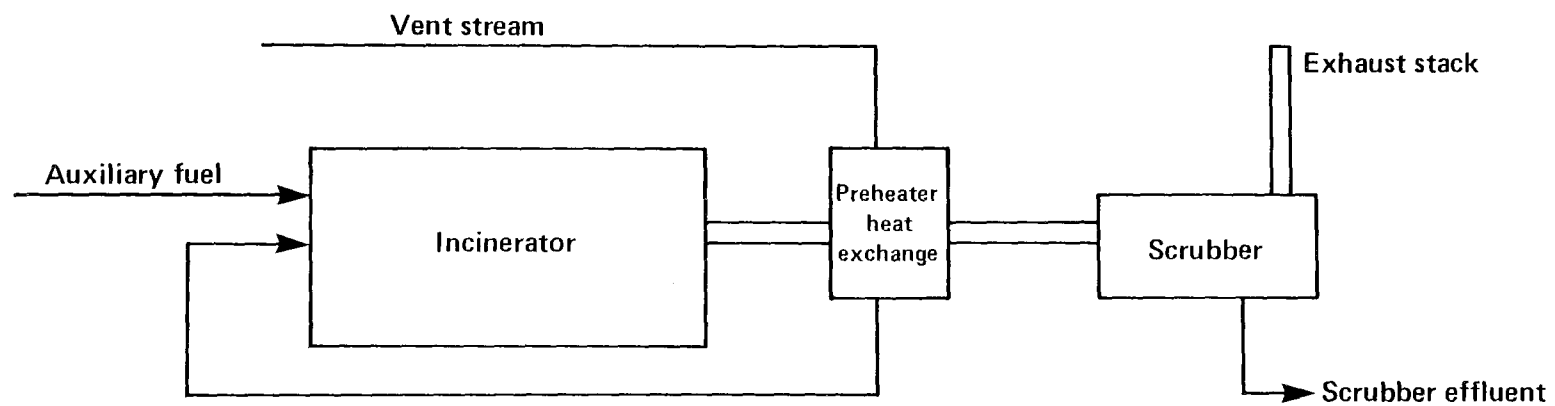
Figure 4-4. Schematic diagram of thermal incinerator system.

necessity of a relatively constant inlet flow rate to sustain stable flame conditions.[53] For a vapor stream with large flow fluctuations, a flare (discussed in Subsection 4.2.3.3) might be more appropriate than a thermal incinerator for organic emission control. Safety may also be a consideration in applying thermal incineration. In the past, storage tank vents at hazardous waste incineration facilities were often integrated with the incinerator feed system. However, this practice has been discontinued because of several accidents.[54] An additional potential limitation to the use of thermal incineration would be the presence of sulfur- or halogen-containing compounds in the vapor stream that would cause corrosion inside the incinerator.[55] In these cases, special construction materials and additional control equipment may be required to prevent release of corrosive combustion products such as hydrochloric acid (HCl) and sulfur dioxide.

Destruction efficiency is a function of the following factors:

- Inlet waste stream characteristics
- Combustion zone temperature
- Residence time
- Degree of mixing in the combustion chamber.

Thermal incineration has been demonstrated to achieve organic destruction efficiencies of at least 98 percent at a temperature of 870 °C and a residence time of 0.75 seconds for most compounds. For halogenated streams, 98-percent efficiency is predicted for incinerators operated at 1,100 °C with a 1-second residence time.[56-61] Consequently, for the purpose of estimating nationwide emissions, a destruction efficiency of 98 percent is used for thermal incinerators.

Organics combustion in a thermal incinerator can produce secondary emissions consisting mostly of nitrogen oxides.[62] However, these emissions should be minimal in a well-designed and -operated incinerator. Combustion of halogenated organic compounds may release halogenated combustion products to the environment although HCl emissions are normally controlled by the use of scrubbers. If a scrubber is used, the scrubber effluent will likely require treatment.

4.2.3.2 <u>Catalytic Incineration of Organic Vapors</u>. Vent gases from fixed-roof storage and treatment tank or air-supported structures covering impoundments are candidates for catalytic incineration. Catalytic incineration is widely used to destroy organic vapors. One of the most common applications is to control hydrocarbon emissions in automobile exhaust systems. The extent to which catalytic incineration is currently used in TSDF is unknown.

Catalytic oxidation (incineration) is a method of controlling organic emissions. In the presence of a catalyst, organic vapors are oxidized, creating carbon dioxide and water. Catalytic oxidation uses a metal- or metallic-alloy-based catalyst to promote higher rates of organics/oxygen reactions at lower temperatures than can be achieved with thermal incineration. Many metal oxides can promote catalytic oxidation of hydrocarbons and carbon monoxide if the reactant temperature is sufficiently high. The noble metals, in particular platinum and palladium, are most active and are used extensively as catalysts, usually in a packed or fixed-bed arrangement. Figure 4-5 illustrates a catalytic incinerator. References 63, 64, 65, and 66 contain detailed discussions of equipment and operating principles.

The use of catalytic converters to meet desired emission control has been extended to virtually every conventional combustion system as well as chemical processes with partly oxidized components, amines, alcohols, acids, etc.[67] An advantage of catalytic oxidation over thermal oxidation is that less NO_x is formed as a result of the lower operating temperature and of operating close to the stoichiometric requirement for oxygen.[68] Operating limitations mitigate some of the advantages of catalytic oxidation. Accumulations of particulate matter, condensed organics, or polymerized hydrocarbons on the catalyst can block active sites and reduce efficiency. Compounds containing sulfur, bismuth, phosphorus, arsenic, antimony, mercury, lead, zinc, tin, or halogens can combine chemically with the catalyst, rendering it useless. In addition, catalytic incinerators are limited to a narrower range of inlet fuel concentration and temperature than are thermal incinerators.
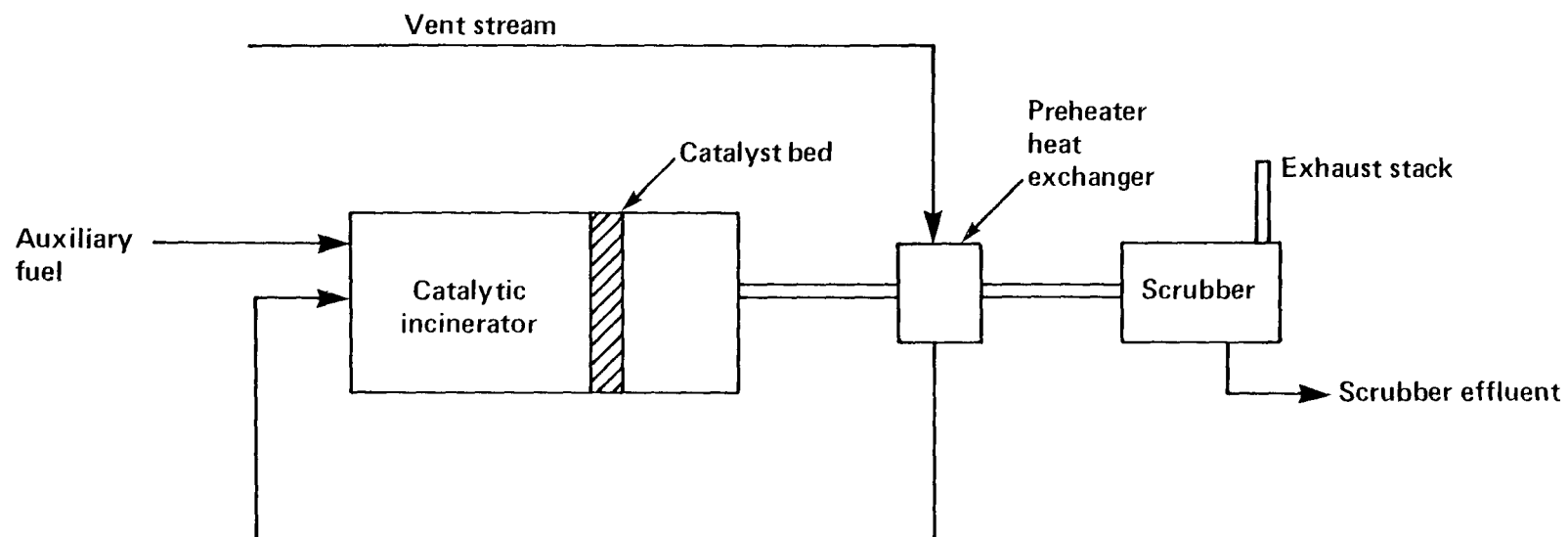
Figure 4-5. Schematic diagram of catalytic incinerator system.

Catalytic incineration is a technology that can be transferred directly from use on other gas streams to use as an add-on control for TSDF operations. One potential application of catalytic incineration is to control overhead organic emissions from an air-stripping column where humidity might impair the performance of gas-phase carbon adsorption.

Catalytic oxidation systems can achieve organic destruction efficiencies approaching 99 percent. Test data for catalytic systems used in other industrial applications for organic emission control indicate that half of the tested units achieved greater than 90 percent destruction of organic compounds. The remaining tested units were capable of achieving 80 or 90 percent organic destruction.[69] The destruction efficiency depends on the inlet temperature, residence time, and temperature profile in the reactor. Two recent EPA-sponsored studies investigated the effectiveness of catalytic incinerators as a means of destroying organics and hazardous/ toxic air pollutants.[70,71] Both studies concluded that destruction efficiencies of 97 to 98 percent were achievable for most of the compounds tested. The first study indicated that chlorinated hydrocarbons were not as effectively destroyed as nonchlorinated compounds but the second showed chlorinated hydrocarbon destruction efficiencies of 97 to 98 percent. On the basis of these test results and considering that catalytic incineration has limited applicability because of the potential for catalyst poisoning, destruction efficiencies of 98 percent appear reasonable for catalytic incineration and were used in the estimation of nationwide emissions.

Cross-media and secondary air impacts associated with the use of catalytic incinerators are minimal, although spent catalyst must occasionally be disposed of. In applications where the feed stream oxygen is substantially depleted because of oxidation of trace contaminants, the same catalyst can reduce inlet NO_x to N_2 and O_2. On occasions where fuel is added to enhance conversion of trace contaminants, a fuel is used that does not contribute to harmful emissions (e.g., the fuel may be H_2 or CH_4).

4.2.3.3 <u>Flares</u>. Flares commonly are used to incinerate waste gases from petroleum refining and petrochemical manufacturing operations. Flares are used for the direct combustion of waste gases. A flare consists of a burner designed to handle varying rates of fuel while burning smokelessly.

In general, flares can be classified as elevated or ground level. An elevated flare is mounted on a stack so as to remove it from the process area for purposes of safety (heat) and nuisance (noise). Auxiliary equipment includes a stack seal (to prevent air intrusion), a knockout drum (for removal of entrained liquids), an ignition system, and the usual ductwork, capture device, and fan subsystem.[72] Figure 4-6 is a schematic of a steam-assisted elevated flare system. Ground-level flares are more versatile than elevated flares but have a much higher capital cost. Ground-level flares generally consist of several burners and combust the material in a refractory chamber or an open pit.[74] Several EPA reference documents[75,76] present detailed information on equipment and operating principles.

Flares can be used for streams with fluctuations in organic concentration, flow rate, and inert content.[77] However, for most efficient operation of a given flare design, there are certain limitations to flare exit velocity and heat content of the waste gas, as described below. Waste streams containing high concentrations of halogens should not be combusted in flares to prevent flare tip corrosion and secondary emissions of SO_x or HCl.[78]

Flare destruction efficiency is determined by characteristics of the waste gas such as flammability limits, autoignition temperature, and density and by flare operating conditions including flame temperature, residence time in the combustion zone, and mixing at the flare tip.[79,80] The EPA sponsored a series of experimental tests to measure flare destruction efficiency.[81,82,83] In these tests, flare destruction efficiency was measured under a wide range of operating conditions. Two important conclusions of the studies were:

1. When flares are operated under conditions that are representative of industrial practices, the combustion efficiencies of the flare plume are greater than 98 percent.[84]

2. Destruction efficiencies of 98 to 99 percent or greater are achieved when flares are operated under stable flame conditions.[85]

The EPA has translated these conclusions into specific minimum requirements for flare designs for controlling equipment leaks in the
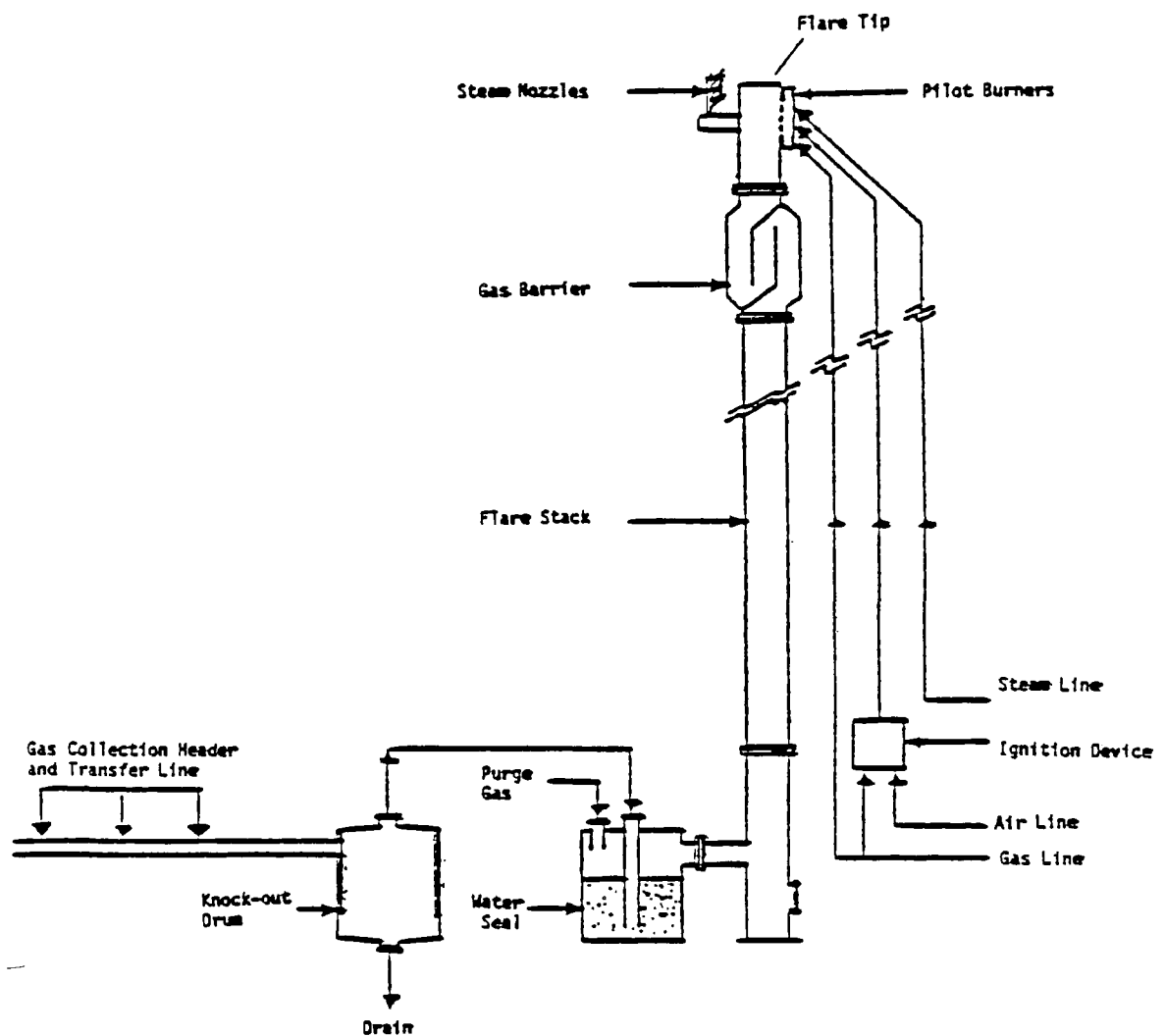
Figure 4-6. Steam-assisted elevated flare system.[73]

synthetic organic chemical manufacturing industry.[86] Minimum flare exit
velocities have been specified based on the heat content of the waste gas
and on whether the flare is steam-assisted, nonassisted, or air-assisted.

There currently are no known applications of flares to TSDF vent
streams, but if vent streams exist with sufficient heat content, a properly
designed and operated flare should achieve a 98-percent destruction effi-
ciency. Flares were not used in the estimates of nationwide emissions, but
they might find application to certain vent streams at TSDF.

Secondary environmental impacts associated with flare operation con-
sist primarily of air emissions of NO_x. However, measurements at two oper-
ating flares show that emissions of NO_x are lower than those for incinera-
tors and considerably lower than those for boilers.[87] Low-frequency com-
bustion noise and high-frequency jet noise constitute a nuisance problem
for elevated flares in populated areas. However, this is relatively easy
to minimize with sound-proof enclosures.

4.2.4 Condensation

Condensers are currently used in TSDF and waste solvent treatment
facilities to remove organic vapors from conveying gas streams in several
types of equipments. Vent gases from steam strippers, distillation
processes, and thin-film evaporators, all of which are used to separate
organic compounds from liquid wastes, are typically sent through condensers
to recover the organics in a more concentrated form.

Condensation is the process of reducing a gas or vapor to a liquid by
lowering its temperature and/or increasing its pressure. Condensation
occurs when the partial pressure of a pollutant in a gas stream equals its
vapor pressure as a pure substance at operating conditions. Reducing the
temperature of the gas stream is more cost effective than increasing the
pressure and is therefore the usual approach.[88] Condensation is relatively
easy if the gas-phase hydrocarbon concentration is high. When concentra-
tions are low, condensation at reasonably achieved temperatures can be
difficult.[89]

Condensers can be classified as contact and surface condensers. In a
contact condenser, the coolant and vapor stream are physically mixed and

exit the condenser as a single stream. Because the condensate would pose a disposal problem or require further processing for recovery of the hydrocarbon, contact condensers are unlikely to be used at hazardous waste TSDF.

Surface condensers are usually in the form of shell- and tube-heat exchangers, such as that shown in the schematic in Figure 4-7. The vapor stream flows into a cylindrical shell within which are numerous small tubes conveying the coolant. Condensation occurs on the cool surface of the tubes; i.e., heat is transferred from the vapor stream to the coolant through a heat exchange surface. The rate of heat transfer (q) is a function of three factors: total cooling surface available, resistance to heat transfer, and mean temperature differential between condensing vapor and coolant. For a single-component vapor stream, this can be expressed mathematically by:[91]

$$q = UA \ \Delta T_m$$

where

    U = overall heat transfer coefficient

    A = heat transfer surface area

  ΔT_m = mean temperature differential.

In practice, the vapor stream will contain multicomponents, air, and at least one other gas, complicating the design procedure.

The coolant used in a surface condenser depends on the saturation temperature (dewpoint) of the organics. If the saturation temperature is high enough, an air-cooled condenser could be used. Other coolants include water at ambient temperature, chilled water, brines, and freons. Chilled water can be used to bring the temperature to as low as 7 °C, brines down to -34 °C, and freons below -34 °C.[92] The major pieces of equipment in a condensation system include the condenser, refrigeration system, storage tanks, and pumps. References 93, 94, and 95 contain detailed discussions of equipment and operating principles.

Condensation processes with significant refrigeration requirements are being used for the recovery of gasoline vapors at bulk gasoline terminals. Condensers have been used successfully (usually with additional control equipment) in controlling organic emissions from petroleum refining and
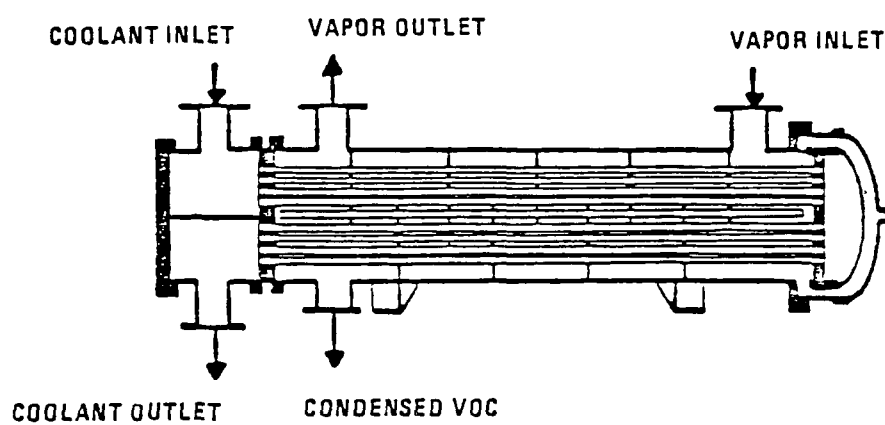
Figure 4-7. Schematic diagram of a shell- and tube-heat surface condenser.[90]

petrochemical manufacturing, dry cleaning, degreasing, and tar dipping.[96]
Probably the most significant application for condensers at hazardous waste
TSDF is in the recovery of organics volatilized in organic removal
processes such as steam stripping or thin-film evaporation.

Condensers are not well suited to treatment of gas streams containing
organics with low boiling points or streams containing large quantities of
inert and/or noncondensible gas such as air, nitrogen, or methane. Air
stripper offgas, for example, would be an unsuitable application; however,
steam strippers and distillation-type processes would be appropriate appli-
cations. Because condensers often operate at temperatures below the freez-
ing point of water, moist vent streams must be dehumidified to prevent the
formation of ice in the condenser. Particulate matter also should be
removed because it may deposit on the tube surfaces and interfere with gas
flow and heat transfer. Generally, condensers are not considered for vent
streams containing less than 0.5 percent organics.[97]

The organic removal efficiency of a condenser is highly dependent on
the characteristics of the vapor stream entering the condenser and on the
condenser operating parameters, as has been discussed. Efficiencies of 50
to 95 percent are achievable depending on organic concentrations, specific
compounds present, and condenser temperature.[98] Appendix F (Section
F.2.2.3) contains a summary of the results of a field evaluation of a
condenser system used to recover organics that were steam-stripped from
wastewater at a plant producing ethylene dichloride and vinyl chloride
monomer. Condenser performance varies with volatility of compounds in
vapors, temperature, condenser coolant, and condenser surface area.
Process simulations were performed with the Advanced System for Process
Engineering (ASPEN) for a steam stripper connected to a two-stage condenser
designed to strip at least 90 percent of the medium volatile compounds
present in one of the model wastes described in Appendix C, Section
C.2.2.[99] Using the dilute aqueous-2 model waste, two-stage condenser
efficiencies in the range of 98.4 to 99.99 percent were shown to be achiev-
able for the high, medium, and low volatile compounds by using a refriger-
ated coolant second stage. This range of efficiencies was used to estimate
the degree of organic removal from overhead vapor streams coming off steam
stripping, distillation, and thin-film evaporation processes. Additional

discussion of condenser usage with organic removal processes is given in Section 4.3 of this chapter.

Cross-media and secondary environmental impacts associated with the use of a surface condenser are primarily the noncondensible gas effluent. Because the coolant does not contact the vapor stream or condensate, recovered organics are normally reusable. If the condensate is not reusable, it is probably incinerated, therefore causing the adverse environmental impacts associated with incineration. Other secondary impacts are associated with the generation of electricity used for air moving and, in some cases, refrigeration.

4.3 ORGANIC REMOVAL PROCESSES AND TECHNOLOGIES

4.3.1 Steam Stripping

Steam stripping involves the fractional distillation of volatile constituents from a less volatile waste matrix. Both batch and continuous steam stripping are commercially proven processes and have been commonly used to remove organics from aqueous streams such as process wastewater. Several references discuss steam stripping in detail, including a steam-stripping manual published by EPA,[100] discussions of the theory and design procedures,[101-104] and discussions of applicability to hazardous wastes.[105-108] The basic operating principle of steam stripping is the direct contact of steam with the waste, which results in the transfer of heat to the waste and the vaporization of the more volatile constituents. The vapor is condensed and separated (usually decanted) from the condensed water vapor. Ultimate control of organics is accomplished by recycling or incinerating the condensed organic layer. A simplified diagram of a steam stripper is shown in Figure 4-8.

Batch steam stripping is used extensively in the laboratory and in small production units where a single unit may have to serve for many mixtures. Large installations also use batch stills if the material to be separated contains solids, tars, or resins that may foul or plug a continuous unit. Batch stills are also used to treat materials that are generated from a cyclical or batch process.[109] Batch processing may offer advantages at hazardous waste facilities because the unit can be operated

Vent (optional)

Vent

Waste in

Storage
and
feed tank

Pump

Feed

Trays
or
packing

Steam
stripper

Steam

Condenser

Condensed
liquids

Vent

Decanter

Decanted water
to feed tank

Vent

Recovered organics

Storage
tank

Recycle, fuel

Effluent
(wastewater treatment)
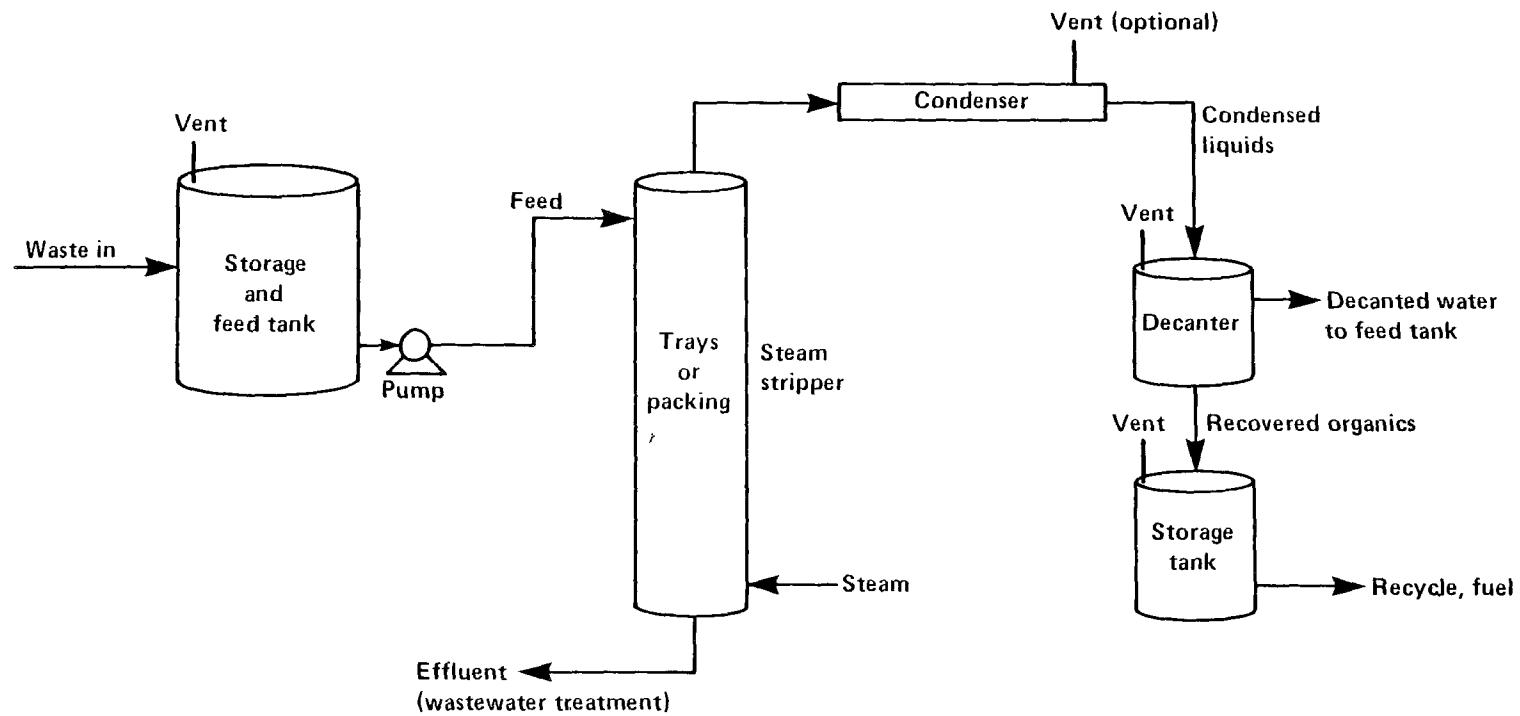
Figure 4-8. Schematic diagram of a steam stripping system.

in a manner most suitable for the particular batch of waste to be stripped. For example, the same unit may be used to remove volatiles from a batch of wastewater, from a waste containing solids, or from a high-boiling organic matrix. The heat input rate and fraction boiled over can be varied for each waste type to obtain the recovery or removal desired for the specific batch of waste. If the system is cleaned between batches, an aqueous waste stream may be generated from the rinse water. This rinse water may be added to a similar batch to be stripped, accumulated in a separate batch for treatment, or sent to a WWT unit. However, wastewater may be generated from cleaning any organic removal or treatment system and would not be unique to batch operations. Continuous steam stripping requires a feed stream that is a free-flowing liquid with a negligible solids content. Solids, including tars and resins, tend to foul the column trays or packing and heat exchangers. Consequently, wastes containing solids may require removal of the solids prior to processing through a continuous steam stripper. Unlike the batch operation, a continuous steam stripper requires a relatively consistent feed composition to maintain a consistent removal efficiency from the waste material.[110] The continuous steam stripper may offer cost advantages over a batch operation for applications in which there is little variation in the type of feed and for relatively high volumes of waste materials.

The products and residues from steam stripping include the condensed vapors (condensate), noncondensible gases, and the treated waste or effluent. The condensate usually is decanted to remove any separate organic layer from the aqueous layer with recycle of the aqueous condensate back to the feed stream. The separate organic layer may be recovered and reused as product or fuel. If the condensate is a single phase of water containing dissolved organics, then additional treatment of the condensate may be necessary for ultimate control of organics. Most commercial processes rely on the formation of a separate organic phase and decanting for economical removal and recovery of organics. Noncondensibles in the overhead stream include gases dissolved in the waste material and very volatile compounds in low concentrations that are not condensed in the overhead system. The noncondensibles leave through the condenser or decanter vent and usually

are vented to the atmosphere or to an incinerator. For example, vinyl chloride and chloroethane in one steam stripping test were found to pass through the condenser and were vented as noncondensibles to an incinerator.[111] The effluent from the steam stripper should be essentially free of the most volatile compounds; however, semivolatiles and compounds that are relatively nonvolatile may still be present in the stripper bottoms or effluent and may require additional treatment for removal.

Steam stripping is applicable to most waste types that have a reasonably high vapor-phase concentration of organics at elevated temperatures (as measured by the vapor/liquid equilibrium coefficient). These waste types are commonly found in TSDF; however, the range of TSDF waste types is so broad that it is not possible to say whether they represent a high or low percentage of the total national wastes. Theoretically, wastes can be processed in a batch still if they can be pumped into the unit and if they produce a residue that can be removed from the still. This batch operation may be applicable for waste streams generated in relatively low quantities. However, batch stripping of sludges with high solids content is not a technology that has been demonstrated and evaluated in full-scale units at TSDF. Consequently, no design or performance data are available for batch stripping of sludges. Some of the difficulties that would be associated with batch stripping of sludges include material handling problems, heat transfer in the unit, long cycle times, and unknown performance. All of these factors would affect the basic design and operation of the unit.

Preliminary treatment such as solids removal or pH adjustment are often used before wastewater is stripped in a continuous unit. Continuous steam stripping has been used routinely in the chemical industry to recover organics for recycle and to pretreat wastewater for organic removal prior to the conventional WWT process. Some common applications include recovery of ethylene dichloride, ammonia, sulfur, or phenol for recycle and removal of phenol, mercaptans, vinyl chloride, and other chlorinated compounds from wastewater.[112] Batch steam stripping appears to be more common at hazardous waste facilities because it is adaptable to different types of wastes that may be received in batches.[113] For any given waste type, pilot-scale evaluations or trials in the full-scale process may be required to optimize the operating conditions for maximum removal at the lowest cost.

Removal efficiencies on the order of 95 to 100 percent are achievable for volatile compounds such as benzene, toluene, and one- or two-carbon chlorinated compounds.[114,115] Batch operations usually provide a single equilibrium stage of separation, and the removal efficiency is determined essentially by the equilibrium coefficient and the fraction of the waste distilled. The efficiency of a continuous system is related to the equilibrium coefficient and the number of equilibrium stages, which is determined primarily by the number of trays or height of packing. The organic removal efficiency also is affected by the steam input rate, column temperatures, and, in some cases, the pH. Temperature affects the solubility and partition coefficient of the volatile compound. The liquid pH also may affect the solubility and treatability of specific compounds, such as phenol. In principle, the removal efficiency in a multistage system can be designed to achieve almost any level. In practice, removal efficiencies are determined by practical limits in the column design (such as maximum column height or pressure drop) and cost. Consequently, steam stripping is difficult to characterize in terms of maximum achievable performance with respect to percent organic emission reduction or organic concentration in the treated waste.

Several evaluations of steam stripper performance have been reported in the literature. The results of five such evaluations are presented in Appendix F. Wastewater containing methylene chloride, chloroform, and carbon tetrachloride was treated by steam stripping at a chemical plant (Section F.2.3.1.1). An inlet concentration of approximately 6,000 ppm organics was reduced to less than 0.037 ppm for an overall removal efficiency of about 99.999 percent. The effluent from the stripper required no further treatment and was discharged directly to a river under a National Pollutant Discharge Elimination System (NPDES) permit.

The steam stripper at one plant (Section F.2.3.1.2) was used to strip VO, as defined by purge-and-trap analytical procedures, from industrial wastewater. The major component was 1,2-dichloroethane, which was removed from the wastewater at an efficiency of 99.998 percent. The removal of total organics, which generally included chlorinated compounds with one to two carbon atoms, averaged 99.8 percent.

The test at a chemical manufacturing plant (Section F.2.3.1.3) evaluated the removal of nitrobenzene and nitrotoluene from wastewater. These compounds are less volatile than the compounds in the wastewater at the first plant. The removal efficiency for nitrobenzene and 2-nitrotoluene ranged from 91 to 97 percent with an overall organics removal of 92 percent.

The steam stripper at a fourth chemicals manufacturing plant (Section F.2.3.1.5) is used to remove relatively volatile compounds (methylene chloride, chloroform, and carbon tetrachloride) from wastewater. The removal of the major component, methylene chloride, was 99.99 percent. The removal of total organics was 98 percent.

Four batches of waste were evaluated in a batch steam stripping process used to reclaim organic solvents (Section F.2.3.1.4). The types of compounds present in the waste included both very volatile compounds and some considered to be semivolatiles because of their solubility in water. The removal of the most volatile compounds was on the order of 99 percent with occasionally lower values for specific compounds (e.g., 91 percent for acetone, 87 to 94 percent for 1,1,1-trichloroethane, and 74 percent for ethyl benzene). The removal of total organics from the batches ranged from 94 to 99.8 percent.

At a solvent recycling plant (Section F.2.3.4.1), tests were conducted on two batches of waste processed through a batch steam distillation unit. In the first batch, removal of individual compounds ranged from 36 to 92 percent and total organics removal was 76 percent. In the second batch, removal of individual compounds ranged from 12 to 91 percent and total organics removal was 91 percent. In this latter batch, a major portion of the total organic content of the waste consisted of the most volatile compound.

Steam stripping removal efficiencies of 99.99, 94.5, and 16.5 percent for high, medium, and low volatile compounds, respectively, were used to estimate the effects of organic removal from wastes on nationwide emissions. These removal efficiency estimates were developed using the ASPEN process simulation computer program for a steam stripper applied to the dilute aqueous-2 model waste described in Appendix C, Section C.2.2.[116]

The design goal for the steam stripper was to achieve at least 90 percent removal of the medium volatile components of the model waste.

Emission sources associated with a steam stripping operation include: (1) tank vents (e.g., feed storage, solids removal, decanters, condensate receivers), (2) the overhead condenser vent, and (3) leaks from transfer and handling operations (pumps, valves, flanges). The effluent or bottoms from the steam stripper also may be emission sources if they contain any residual volatiles or an appreciable quantity of semivolatiles, especially if the effluent is subsequently processed through an aerated system or placed in an impoundment with a long retention time.

The major secondary air impact associated with steam stripping is the generation of emissions in the production of steam. Emissions from industrial boilers include particulate matter, methane and other organics, SO_x, CO, and NO_x. The quantity of these pollutants generated is a function of the amount of steam produced and the type of fuel used in the boiler (e.g., No. 2 fuel oil, No. 6 fuel oil with high or low sulfur content, and natural gas). Other secondary emissions such as flyash and scrubber effluent are also produced from the generation of electricity.

4.3.2 Air Stripping

Air stripping is a process that uses forced air to remove volatile compounds from a less volatile liquid. The contact between air and liquid can be accomplished in spray towers, mechanical or diffused-air aeration systems, and packed towers.[117] The focus of this section is on packed tower air strippers because the vapor-laden air can be sent to a control device for ultimate control of organic air emissions, whereas the other devices rely upon dilution in ambient air to avoid environmental problems. In packed towers, the liquid to be treated is sprayed into the top of a packed column and flows down the column by gravity. Air is injected at the bottom of the column and rises countercurrent to the liquid flow. The air becomes progressively richer in organics as it rises through the column and is sent to a control device to remove or destroy organics in the air stream. See Figure 4-9 for a schematic of a typical air stripping system with gas-phase organic emission control.

Overhead vapors

Control device

Vented air

Control device residue
(e.g., spent carbon)

Vent

Feed

Waste in

Storage
and
feed tank

Air
stripper

Pump

Effluent

Air
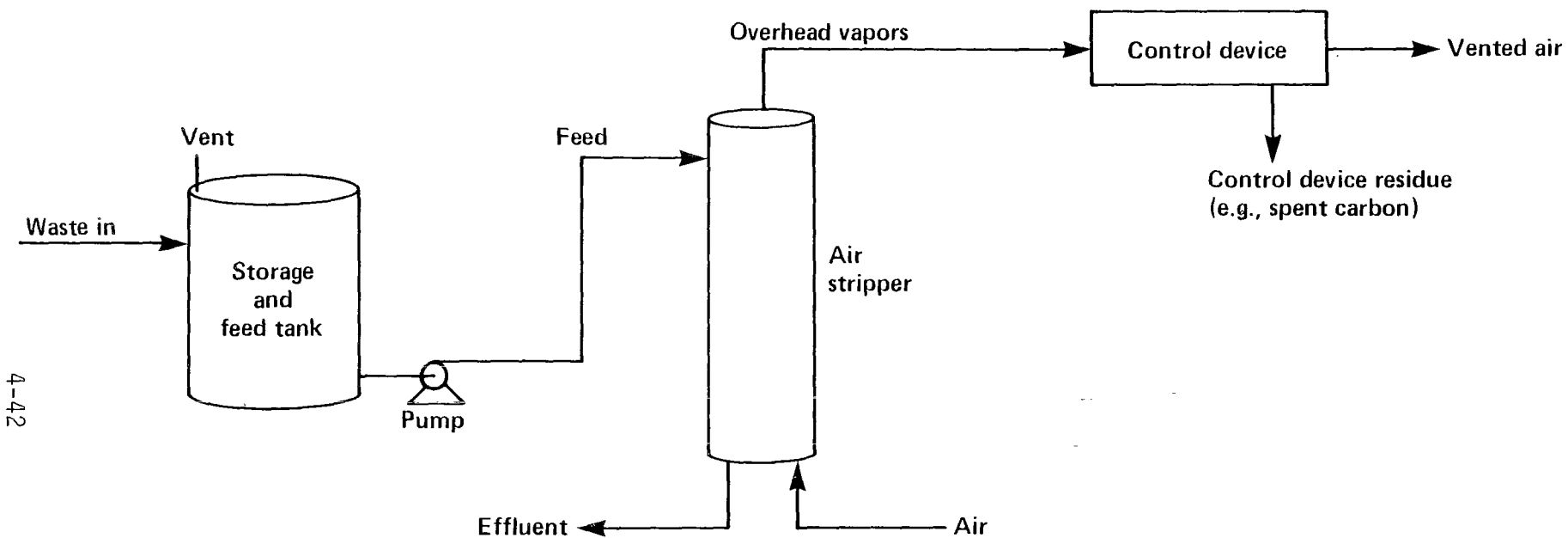
Figure 4-9. Schematic diagram of an air stripping system.

The principle of operation is the equilibrium differential between the concentration of the organics in the waste and the air with which it is in contact. Consequently, compounds that are very volatile are the most easily stripped. The packing in the column promotes contact between the air and liquid and enhances the mass transfer of organics to the air. The residues from air stripping include the organics-laden air that must be treated and the water effluent from the air stripper. This effluent will contain very low levels of the most volatile organic compounds; however, semivolatile compounds that are not easily air stripped may still be present and may require some form of additional treatment before final disposal. The process does not offer a significant potential for recovery and reuse of organics. Condensers generally are not used to recover the stripped organics because of the large energy requirements to cool the large quantity of noncondensibles (primarily air) and to condense the relatively low vapor-phase quantities of organic compounds. Thermal and catalytic incinerators and carbon adsorption units are the most common control devices used for control of the overhead gas stream from air strippers. Fixed-bed carbon adsorption systems offer some potential for recovery of organics; however, the decision on type of control (organic destruction or recovery) is usually based on economics.

Air stripping has been used primarily on dilute aqueous waste streams with organic concentrations that range from a few parts per billion to hundreds of parts per million. The feed stream should be relatively free of solids to avoid fouling in the column; consequently, some form of solids removal may be required for certain aqueous hazardous wastes. In addition, dissolved metals that may be oxidized to an insoluble form should be removed. Equipment may be designed and operated to air-strip organics from sludges and solids in a batch operation; however, this application has not been demonstrated extensively and is not a common practice. The major industrial application of air stripping has been in the removal of ammonia from wastewater.[118] In recent years, the use of air strippers has become a widely used technology in the removal of volatile compounds from contaminated groundwater.[119,120]

Packed towers can achieve up to 99.9 percent removal of volatiles from water.[121] The major factors affecting removal efficiency include the equilibrium between the organics and the vapor phase (usually measured by Henry's law constant for dilute aqueous wastes) and the system's design, which determines mass transfer rates. Removal efficiency increases as the equilibrium coefficient increases; consequently, the extent of removal is strongly affected by the type of waste and the volatility of the individual VO constituents. Mass transfer rates (and removal efficiency) are also a function of the air:water ratio, height of packing, and type of packing.[122] The operating temperature is also an important variable that affects efficiency because of its direct effect on the vapor/liquid equilibrium. Higher temperatures result in higher vapor-phase concentrations of VO and higher removal rates. Air strippers have operational difficulties in freezing weather that may require heating the input waste stream, heating and insulating the column, or housing the operation inside an enclosure. Air strippers are typically designed to remove key or major constituents. Compounds more volatile than the design constituent are removed at or above the design efficiency. and less volatile compounds are removed at a lower efficiency. Numerous vendors are available for the design and installation of air strippers. As is the case with steam strippers, these vendors usually require pilot-scale tests on the actual waste material to design the column and to guarantee minimum removal efficiencies.

Emission sources associated with an air stripping operation include tank vents (storage or feed tanks, preliminary treatment tanks) and equipment used to transfer and handle the waste (pumps, valves, etc). The air leaving the stripping column usually is treated by incineration (with destruction efficiencies of 98 percent or higher) or carbon adsorption (with removal efficiencies of 95 percent or higher if carbon breakthrough is monitored). The choice between incineration and carbon adsorption depends on the specific conditions at the facility. For example, high relative humidity in the air stream leaving the air stripper may adversely affect the adsorption capacity.of a carbon bed. This could be avoided by choosing incineration. However, if the air stream contains chlorinated

organics, the incinerated air stream may need to be scrubbed to remove HCl, leading to higher costs. In this case, it might be better to choose carbon adsorption and design to avoid the humidity problem.

The effluent from the air stripper may be an emission source for semivolatiles that are not removed efficiently, especially if subsequent processing includes placement in an evaporation pond or disposal impoundment. Air stripping could be used to reduce organics from wastewater prior to a wastewater treatment operation.

An air stripper was evaluated at a Superfund site (Section F.2.3.2.1) where it is used to remove organics from the leachate collected at the site. The evaluation focused on optimizing the removal efficiency for organic components that represented a relatively wide range in volatility. During one test, the removal of the most volatile constituents (1,2,3-trichloropropane and xylene) ranged from 88 to 98 percent. The removal of semivolatiles such as aniline, phenol, methylphenol, and ethylbenzene ranged from 53 to 70 percent. The removal of total organics averaged 99 percent.

Air stripping is not specifically used to evaluate the effects of organic removal from wastes on nationwide emissions. Because most air stripping applications have been to streams containing less than a few hundred parts per million organic, its usefulness in reducing TSDF organic emissions may be limited. However, there may be some site-specific situations nationally that would be appropriately treated by air stripping.

Cross-media and secondary air impacts from air stripping are much less than those from steam stripping because less energy is required. The major utility is electricity for blowing air and pumping the liquid, plus auxiliary fuel needed for incineration or steam needed for carbon regeneration. Secondary emissions are generated from coal-fired generators that produce electricity and include particulate matter, CO, SO_x, and NO_x. Cross-media impacts would include small quantities of ash if the vent stream is incinerated and spent carbon if the vent stream is treated with carbon adsorption.

4.3.3 Thin-Film Evaporation

Thin-film evaporators (TFE) are designed to promote heat transfer by spreading a thin-layer film of liquid on one side of a metallic surface

while supplying heat to the other side.[123] The unique feature of this
equipment is the mechanical agitator device, which permits the processing
of high-viscosity liquids and liquids with suspended solids. However, if
solid particles are large, a coarse filtration operation may be required to
pretreat the waste stream going to the TFE. The mechanical agitator pro-
motes the transfer of heat to the material by exposing a large surface area
for the evaporation of volatile compounds and agitates the film to maintain
the solids in suspension without fouling the heat transfer area. Heat can
be supplied by either steam or hot oil; hot oils are used to heat the mate-
rial to temperatures higher than can be achieved with saturated steam
(>100 °C). TFE can be operated at atmospheric pressure or under vacuum as
needed based on the characteristics of the material treated. A TFE is
illustrated in Figure 4-10.

The two types of mechanically agitated TFE are horizontal and
vertical. A typical unit consists of a motor-driven rotor with longitudi-
nal blades that rotate concentrically within a heated cylinder. The rotat-
ing blade has a typical tip speed of 9 to 12 m/s and a clearance of 0.8 to
2.5 mm to the outer shell. In a vertical design, feed material enters the
feed nozzle above the heated zone and is transported mechanically by the
rotor and grating down a helical path on the inner heat transfer surface
while the volatile compounds are volatilized and leave the evaporator on
the top. The vapor-phase products from TFE are condensed in a condenser,
and the bottom residues are collected for disposal.

TFE have been used widely for many years in a number of applications
such as processing of chemicals, pharmaceuticals, plastics, and foods.[124]
Because of their unique features, their use in chemical and waste material
processing has expanded rapidly. The flexibility in operating temperature
and pressure add potential to TFE for recovering low-boiling-point organics
from a complex waste matrix.

Although TFE can be used to remove varying levels of organics from a
waste stream, when applied to hazardous petroleum refinery sludges, the
most suitable mode of operation is to evaporate the water and volatiles and
leave most of the hydrocarbons that are less volatile than water.

Vent

Condenser

Vent

Decanter — Decanted water

Vent

Recovered organics

Vent

Storage and feed tank

Pump

Thin-film evaporator

Storage tank — Recycle

Bottom stream
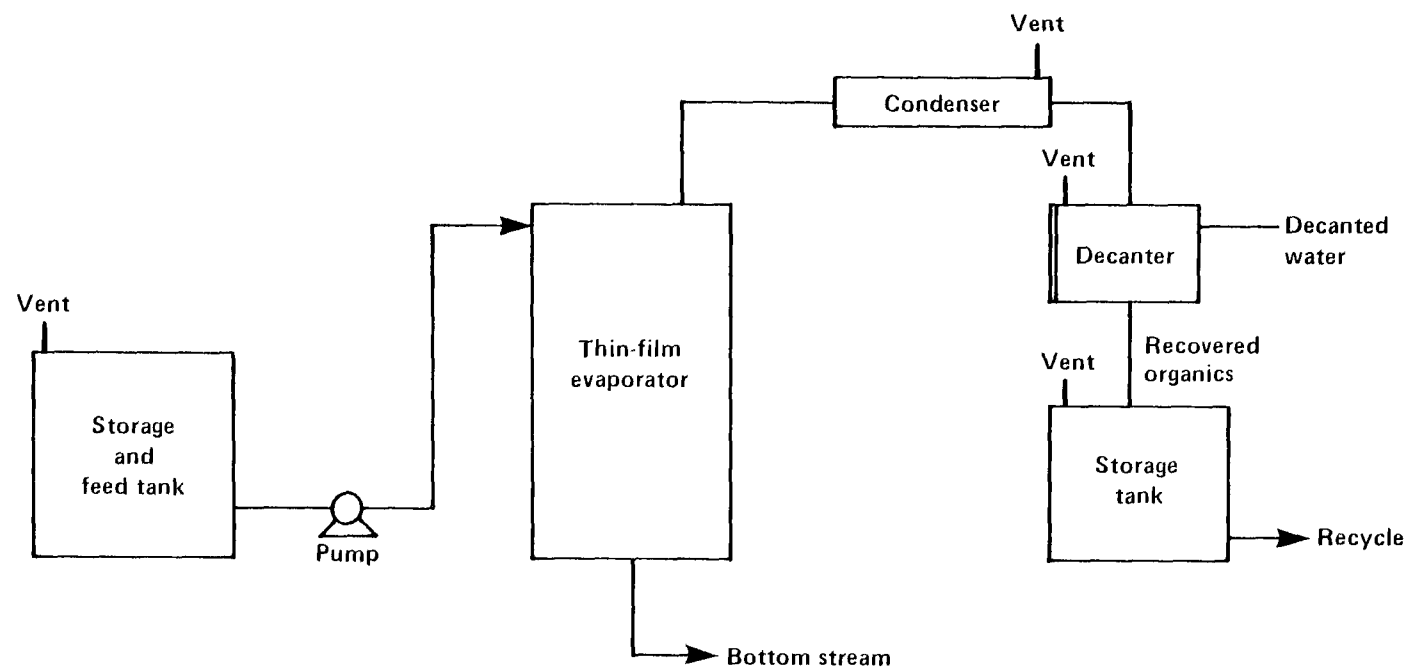
Figure 4-10. Schematic diagram of a thin-film evaporator system.

With this mode of operation, the TFE bottom residue contains only low concentrations of both volatile and semivolatile organic compounds and thus has a low potential for air emissions after ultimate disposal. This mode of operation was used during a pilot-scale test discussed below. Waste forms suitable for TFE treatment include organic liquids, organic sludge/ slurry, two-phase aqueous/organic liquids, and aqueous sludges. TFE would not be used as a means of treating dilute aqueous waste because of the high water content in the waste.

Although TFE technology is readily available, as with other organic removal techniques, a pilot-plant study is usually conducted before full-scale operation to determine the suitability of the TFE for pretreating a particular waste stream and to identify optimal operating conditions. The EPA recently sponsored a pilot-scale test to assess the performance of a TFE in removing organics from the different types of petroleum refining wastes.[125] In that study, 98.4 to 99.99 percent of the volatile and 10 to 75 percent of the semivolatile compounds were removed from the sludge. These results suggest that a TFE can be used to reduce organics substantially in refinery sludges that are currently land treated. No commercial-scale TFE installations have been identified that process the types of wastes normally handled by TSDF. However, two installations of TFE used to recover organics from waste streams have been documented in the literature and may have some relevance for TSDF operations.[126] In one installation (Section F.2.3.3.3), a hazardous waste recycling plant operates a TFE under vacuum to separate approximately 95 percent of a feed stream that consists of waste oils, a small amount of solids, and approximately 5 percent organics. In that operation, toluene is removed from the oily wastes at less than 85 percent efficiency while both chloroform and methylene chloride are removed at greater than 99 percent efficiency. However, that installation reportedly has significant organic air emissions through the vacuum pump vent although no estimate was given for the magnitude of the emissions. At another organic solvent reclamation and recycling plant (Section F.2.3.3.2), a TFE operating at atmospheric pressure was able to remove approximately 76 percent of the acetone and 30 percent of the xylene from a contaminated acetone waste. Air samples from the process vent at that operation indicated that air emissions were

negligible. At a solvent recycling plant (Section F.2.3.3.1), a TFE showed removal efficiencies of 45 to 99 percent for individual volatile and semivolatile compounds and yielded a total organic removal efficiency of 74 percent.

Factors likely to affect or limit the applicability or removal efficiency of TFE include:

- Large changes in the properties of the waste being treated, which could cause fouling of the TFE unit.

- The requirement for separation of water and condensed organics when water is evaporated from the waste stream, which adds to the operating expense of the unit.

For the purpose of estimating nationwide emissions, removal efficiencies used for TFE are 99.8, 65.9, and 20.7 percent for high, medium, and low volatile compounds, respectively. These values are based on the EPA-sponsored pilot test referenced above. This test was judged to be more representative of TFE operations at TSDF than the other data cited.

Emission sources associated with the operation of a TFE include (1) tank vents (blending or storage tanks and product accumulation tanks); (2) the overhead condenser vent; and (3) fugitive leaks from pump seals, valves, etc. The condensate recovered from TFE is a concentrated organic and may produce organic air emissions when stored and transferred. The bottom residue from TFE should have a low organic content; however, some semivolatile compounds may remain in the waste and could be emitted in subsequent handling or disposal.

Secondary environmental impacts are those associated with the generation of energy for heating the TFE. Steam or hot oil produced in industrial boilers is commonly used to provide TFE heating. Pollutants from the boiler could include CO, SO_x, NO_x, and particulate matter; the quantity emitted depends on the type of fuel used and the quantity burned. When carbon canisters are used to control organic air emissions associated with TFE, the ultimate disposal of the spent carbon canister constitutes a cross-media impact.

4.3.4 Batch Distillation

Batch distillation is a commonly used process for recovery of organics from wastes. Its principal use is for recovery of valuable organic

chemicals for recycling or reuse and the re-refining of waste oil as discussed later in this section. Examples of its use show that it can be applied to wastes and reduce the organic air emission potential of those wastes by separating the volatile compounds from the wastes. Although it has been applied to aqueous wastes, it has been more typically applied to predominantly organic wastes.

The simplest form of distillation is a batch operation that consists of a heated vessel (called the pot), a condenser, and one or more receiving tanks. This process is identical in principle to batch steam stripping except that the waste charge is heated indirectly instead of by direct steam injection. The waste material is charged to the pot and heated to boiling; vapors enriched in organics are removed, condensed, and collected in receiving tanks. The distillation is continued to a cutoff point determined by the concentration of organics in the condensate or the concentration of organics remaining in the batch. A common modification is to add a rectifying column and some means of returning a portion of the distillate as reflux (see Figure 4-11). Rectification enables the operator to obtain products from the condensate that have a narrow composition range. Different distillate cuts are made by switching to alternate receivers, at which time the operating conditions may be changed. If the distillate is collected as one product, the distillation is stopped when the combined distillate reaches the desired average composition.[127] Several references are available that discuss the design and operation of batch distillation units.[128-134] The batch still is operated at a temperature determined by the boiling point of the waste, which may increase with the time of operation. The distillation can be carried out under pressure or under vacuum. The use of vacuum reduces the operating temperature and may improve product recovery, especially when decomposition or chemical reaction occurs at higher temperatures.

Batch distillation provides a means for removing organics from a waste matrix and recovery of the organics by condensation for recycle, sale as product, or for fuel. The products and residues include the condensate that is enriched in organics and recovered, noncondensibles that escape through the condenser vent, and the waste residue that remains in the pot.
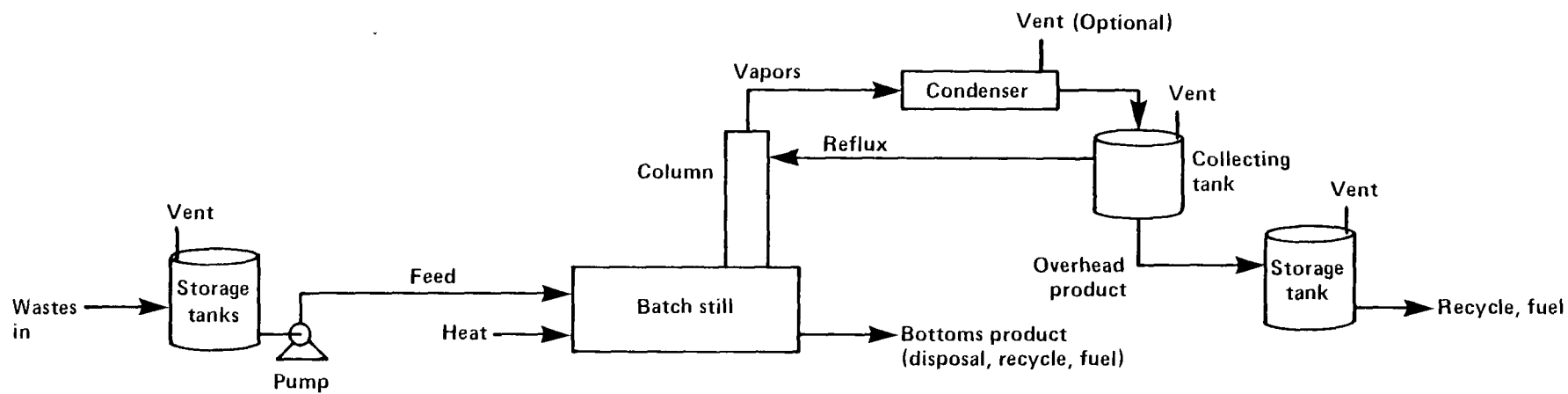
Figure 4-11. Schematic diagram of batch distillation with fractionating column.

The noncondensibles are composed of gases dissolved in the waste and very volatile organic compounds with relatively low-vapor phase concentrations. The waste material after distillation may have been concentrated with high-boiling-point organics or solids that are not removed with the overhead vapors. These still bottoms may be a free-flowing liquid, a viscous slurry, or an organic material that may solidify upon cooling. If the waste material contains water, a separate aqueous phase may be generated with the condensate. This phase may be returned to the batch or processed with additional treatment to remove organics or other contaminants.

Batch distillation may be used for wastes that have a significant vapor-phase concentration of organics at the distillation temperature. If the waste can be pumped and charged to the still pot and the residue can be removed from the pot, then the waste is likely to be treatable for organic removal by this process. Such wastes include dilute aqueous wastes (the operation would be similar to batch steam stripping), aqueous or organic sludges, or wastes with volatiles in a high-boiling-point organic solvent or oil. The batch distillation of sludges has not been demonstrated and evaluated in full-scale units; consequently, the processing of sludges in a batch distillation unit is subject to the same limitations described for the batch steam stripping of sludges (Section 4.3.1). Batch distillation has been used to remove organics from plating wastes, phenol from aqueous wastes, recovery and separation of solvents, and re-refining of waste oils.[135,136] The applicability of batch distillation for a specific waste type can be evaluated by a simple laboratory distillation to assess potential organic recovery. As with other organic removal techniques, the process may require optimization in a pilot-scale or full-scale system for different types of wastes to determine operating conditions that provide the desired distillate composition or percent removal from the waste.

Batch stills usually are operated as a single equilibrium stage (i.e., with no reflux); consequently, the organic removal efficiency is primarily a function of the vapor/liquid equilibrium coefficient of the organics at distillation temperatures and the fraction of the waste boiled over as distillate. The use of a rectifying section yields an overhead product with a composition that can be controlled by the operator. The removal

efficiency for various waste types can be highly variable because of the dependence on both properties of the waste (e.g., organic equilibrium) and the operating conditions that are used. Results of tests conducted on a batch unit at a plant engaged in the reclamation of contaminated solvents and other chemicals are presented in Appendix F (Section F.2.3.4.2). Those tests revealed removal efficiencies on the order of 99.4 to 99.97 percent for organics, including compounds such as methyl ethyl ketone, 2,2-dimethyl oxirane, methanol, methylene chloride, isopropanol, and carbon tetra-chloride.[137] Another test on another unit at the same site evaluated the removal of organics from contaminated solvents and showed that removal efficiencies ranged from 97 percent (for xylene and ethyl benzene) to 99.9 percent (for trichloroethane).[138] These results illustrate that batch distillation has been used successfully to remove organics from aqueous and organic wastes or solvents. In the estimation of nationwide emissions, removal efficiencies used for batch distillation are 99, 18, and 6 percent for high, medium, and low volatile compounds, respectively. The values were derived from a material balance that was performed as part of a process design and simulation study using a model waste stream.[139] The model waste used in the study is the organic liquid model waste described in Appendix C, Section C.2.2.

Emission sources associated with a batch distillation operation include (1) tank vents (blending or storage tanks and product accumulator tanks), (2) the overhead condenser/decanter vent, and (3) leaks from pump seals, valves, etc. The organic condensate recovered from the still is concentrated in organics and may become an organic emission source when it is stored, transferred, or recycled. The waste residue from the still should have a low volatile organic content; however, semivolatile compounds may remain in the waste and may be emitted in subsequent processing or treatment of the waste. Losses of organics through the condenser vent can be controlled when necessary by venting to an incinerator or other control device.

Secondary environmental impacts are those associated with the genera-tion of energy for heating the batch still. Steam from the burning of fuel in industrial boilers is typically used in the industry to provide this

heating. Pollutants from the boiler include particulate matter, SO_x, $\dot{C}O$, and NO_x; the quantity emitted depends on the type of fuel (coal, fuel oil, or natural gas) and the quantity of fuel burned.

4.3.5 <u>Dewatering</u>

As used herein, dewatering refers to solid-liquid separation achieved by filtration or centrifugation. Such devices normally are characterized according to the force used to achieve the desired separation. At TSDF, solid-liquid separation most often is achieved by filtration rather than centrifugation. Filtration is achieved by passing the waste stream through a filtering medium, often a textile product, using force that may be applied in any of several ways. Press-type filters consist of a series of plates covered with a filtering medium and enclosed in a frame. Separation is achieved by filling the void spaces between plates with the input material and then applying pressure to force the plates together and generate the desired separation. Examples of this type of filter include plate and frame, recessed plate, and pressure leaf filters.[140] Filtration force also may be applied by using atmospheric pressure on one side of the filter medium while the other side is maintained at greater or lesser than atmospheric pressure. Examples of this type of filter include rotary drum vacuum and rotary drum pressure filters. In rotary drum vacuum filters, the driving force is achieved by reducing the pressure inside a rotating drum to below atmospheric. The drum is covered with a filter medium that builds up a cake of solids that contributes to filtration efficiency. The rotary drum pressure filter uses the reverse principle of applying greater than atmospheric pressure to the inside of the rotating drum. In these filters, the filtering medium is inside the drum. Advantages of the vacuum filter include its adaptability to continuous operation and the ease with which the filter material can be cleaned and maintained.[141] In recent years, belt filter presses have become one of the more widely used types for many applications. These filters use a combination of gravity and pressure to apply force across the filter medium. In belt filter presses, the input stream is applied to a horizontal moving belt that is covered with filter material. Gravity forces cause partial separation of the liquid from the solids in the stream. As the belt continues to move, it approaches a second moving belt, and the two move along together over a

series of rollers that force the belts closer and closer together, creating pressure on the material between the two belts. The belts separate for solids removal, and the filter medium separates from the underlying supporting web. At this point, the filter medium can be washed continuously. The ease of continuous washing is one of the primary advantages of the belt filter press.[142] Other advantages include the adaptability to continuous operation and the higher throughputs handled relative to other types of filters. Exit streams from a filtering or dewatering operation include the filtrate, which is mostly free of solids, and the filter cake, which generally has a sufficiently low moisture content to be handled using solids handling techniques. A schematic diagram of a dewatering system is illustrated in Figure 4-12.

Dewatering is applicable to any waste stream that consists of a sludge or slurry such as petroleum refinery sludges. When used for this application, toxic metals remain in the filter cake, which could continue to be land treated or may be fixated and landfilled, while the liquid passes through a separation process where oil (which will contain a large fraction of the organics) is recovered for recycle. Little data have been identified that can be used to estimate the emission reduction achieved by dewatering. However, Chevron Research Company has conducted tests that indicate as much as 90 percent of the oil in refinery sludges can be recovered by dewatering and that oil recovery is improved substantially if the filtration or centrifugation step is followed by a drying step.[143] At an EPA-sponsored test at a Midwest refinery, oil removal using a belt filter was found to be 78 percent for an API separator sludge and 66 percent for a dissolved air flotation (DAF) float.[144] If the recovery efficiencies obtained in the tests can be achieved in full-scale applications, an equivalent reduction in emissions from land treatment or landfill operations would be expected. Dewatering devices were not used in estimating nationwide emissions, but they might be used in lieu of other emission control options in some circumstances.

Emissions during dewatering would come from pumps, valves, storage, and other handling operations and also from any exposed waste surfaces at

Waste in

Storage tank

Pump

Control device

Vent

Dewatering device

Vented dewatering enclosure

Filter cake

Filtrate to WWT
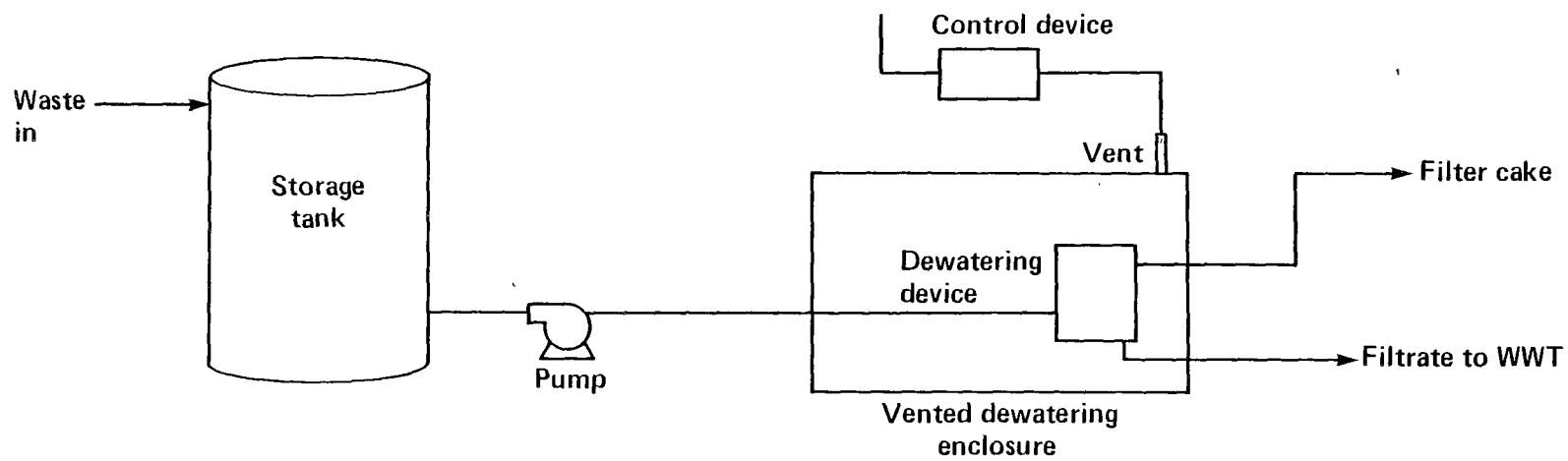
Figure 4-12. Dewatering system with enclosed dewatering device.

the dewatering device. At the test of the belt filter press cited above, measured air emissions were equal to 21 percent of the volatiles in the API separator sludge and 13 percent of the volatiles and 22 percent of the semivolatiles in the DAF float. When vacuum filters are used, emissions would occur with the vacuum pump exhaust. Control of emissions could be achieved by enclosing the operation where necessary and evacuating the enclosure to a capture device such as a carbon adsorption unit. Vacuum pump exhaust also could be controlled with a carbon adsorption unit or other control device. If carbon canisters are used to control emissions from dewatering operations, periodic disposal of spent carbon would be required and would constitute a cross-media impact. If fixed-bed carbon adsorption is used, additional environmental impacts would be associated with disposal or combustion of the recovered organics and condensate, and with fuel combustion used to produce steam for carbon regeneration. Specific impacts would depend on the combustion process and type of fuel used.

4.4 HAZARDOUS WASTE INCINERATION

Incineration is an engineered process that uses thermal oxidation of a bulk or containerized waste to produce a less bulky, toxic, or noxious material. Combustion temperature, residence time, and proper mixing are crucial in controlling operating conditions.[145,146] Of the several types of waste incineration systems, four are generally cited as being the most useful and having the greatest potential for application to wastes processed at TSDF. They are liquid injection, rotary kiln, fluidized-bed, and multiple-hearth incinerators. The type of incinerator selected for a particular installation depends on the waste type and composition as well as other factors such as whether the waste is in bulk or containerized.

Liquid injection incinerators are versatile and can be used to dispose of virtually any combustible liquid that can be pumped. The liquid waste must be converted to gas prior to combustion. This change is brought about in the combustion chamber and is generally expedited by increasing the waste surface area by atomization.[147] Liquid injection incinerators operate at temperatures between 820 and 1,600 °C. Gas-phase residence times range from 0.1 to 2 s.

Rotary kilns are versatile units that can be used to dispose of solids, liquids, slurries, and gaseous combustible wastes. Rotary kilns are long, cylindrical rotating furnaces lined with firebrick or other refractory material in which solids are combusted by themselves or are incinerated by combustion of an auxiliary fuel or liquid wastes. Combustion temperatures range from 870 to 1,600 °C depending on the waste material characteristics.[148] Solids residence time varies from seconds to hours, depending on the type of waste. Unless the kiln is very long (i.e, provides a larger residence time), some type of secondary burning chamber usually is required to complete combustion of the solid waste. The heat release per unit volume is generally quite low, but the rotary kiln provides a method of mixing solids with combustion air and can be operated at temperatures in excess of 1,400 °C that are unavailable in other types of systems.

A fluidized-bed incinerator consists of a bed of inert granular material fluidized by hot air onto which the waste and auxiliary fuel is injected.[149] The waste in turn combusts and returns energy to the bed material; thus, heat release per unit volume is generally higher than for other types of incinerators. Fluidized-bed incinerators operate at temperatures below the softening point of the bed medium, usually around 450 to 850 °C.[150] The residence time is generally around 12 to 14 s for a liquid waste and longer for solid wastes. This type of incinerator is suited particularly to heavy sludge and to certain types of organic/inorganic mixtures. The inorganic material will stay in the bed and can be removed as ash. Scrubbing of flue gases usually is required to remove fine particulates, and subsequent flue gas treatment is required for halogen, sulfur, and phosphorus compounds.

The multiple-hearth incinerator was designed for the incineration of low heat content waste such as sewage sludge. It generally uses large amounts of auxiliary fuel and is large in size. A multiple-hearth unit generally has three operating zones: the uppermost hearths where feed is dried (350 to 550 °C), the incineration zone (800 to 1,000 °C), and the cooling zone (200 to 350 °C).[151] Exit gases have good potential for heat recovery, being around 300 to 600 °C. Temperatures on each hearth can be

maintained using supplemental fuel. Multiple-hearth units may be suitable for hazardous sludge disposal, although it may be necessary to add an afterburner to destroy unburned hydrocarbons that volatilize on the uppermost hearths. Several incinerator types are shown in Figure 4-13.

The cost of operating an incinerator can be reduced by recovering and using the heat generated by the combustion of waste. Primary heat recovery can be employed by using the incinerator exhaust to preheat the incoming waste stream. Secondary heat recovery, such as a waste heat boiler, can also be used if the production process can make use of the steam generated. Heat recovery is shown in the incinerator illustration in Figure 4-13.

Incineration under proper control and using proper techniques will provide total destruction of all forms of hazardous organic wastes.[152] There are two basic types of wastes: (1) combustible wastes, which will sustain combustion without auxiliary fuel; and (2) noncombustible wastes, which usually contain large amounts of water or other inert compounds and will not sustain combustion without auxiliary fuel. Organic liquid and sludge are most suitable for incineration because of their heat content. Aqueous sludge, two-phase aqueous/sludge, and organic-containing solids may be incinerated with auxiliary fuel to destruct hazardous organics. Dilute aqueous waste would not be suitable for direct incineration because of its high water content.

Of the four types of incineration, liquid injection and rotary kiln have been proven to destruct hazardous waste and to be commercially available; fluidized-bed and multiple-hearth are less frequently used technologies. However, fluidized-bed incinerators may have greater potential because of their compact design, which results in relatively low capital cost, and their general applicability to solids, liquids, gases, and wastes containing inorganics.[153]

With proper temperature, residence time, and turbulence control, most incinerators are able to destruct most hazardous wastes. An incinerator system with additional afterburner and flue gas handling systems can be operated to achieve 99.99 percent or better destruction or removal efficiency (DRE)[154] for most wastes to meet EPA regulations. However, the desired destruction efficiency may not be achievable for some recalcitrant
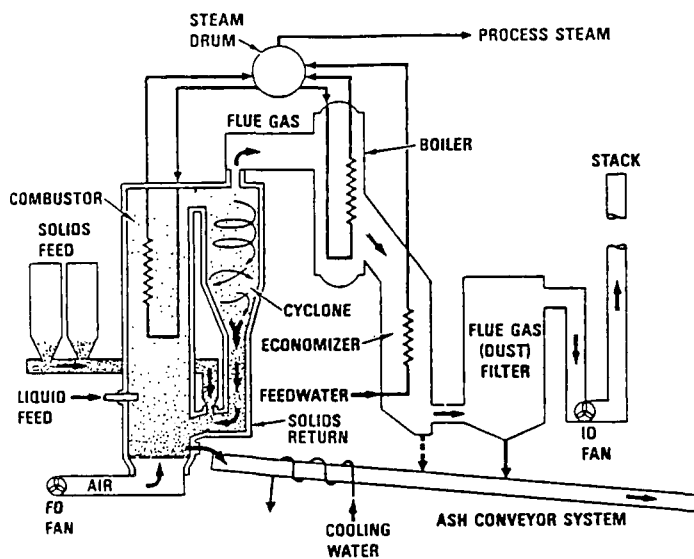
Fluidized-Bed Incinerator
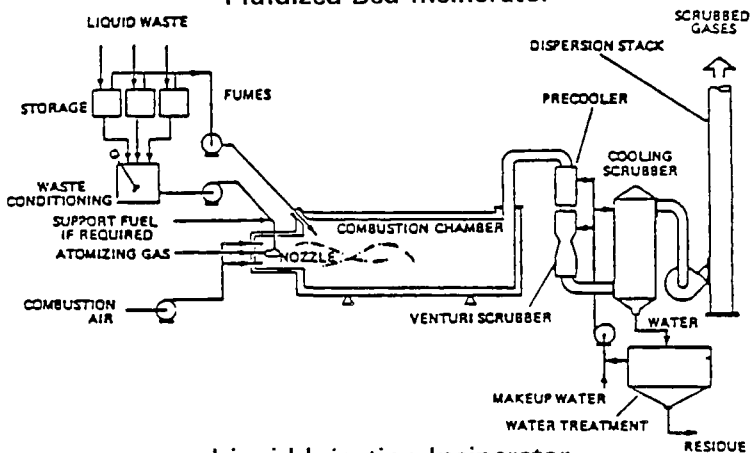
Liquid Injection Incinerator
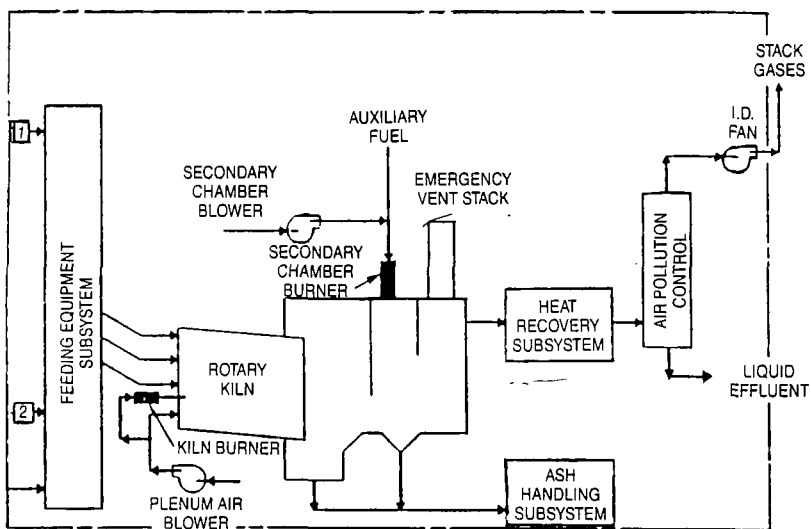
Rotary Kiln Incinerator

Figure 4-13. Hazardous waste incinerators.

or halogenated compounds without substantial increases in incinerator operating cost; therefore, the major limitations on incineration would be the type of waste to be incinerated and the cost of incineration. For the purpose of estimating nationwide emissions, a destruction efficiency of 99.99 percent is used for hazardous waste incineration, which is the EPA regulatory requirement for hazardous waste incineration.

There are three major cross-media and secondary environmental impacts associated with an incinerator system: (1) bottom and fly ash formation and handling, (2) scrubber effluent and sludge formation and disposal, and (3) air emissions from the incinerator exhaust stack. Hazardous ash or sludge needs to be disposed of ultimately at RCRA-permitted landfills, or nonhazardous ash can be incorporated into other useful processes such as production of cement products; scrubber effluent needs to be treated before discharge; and the exhaust gas must meet EPA emission standards. Any heavy metals in the feed stream would likely show up either in the ash or in the scrubber sludge. OSW rules mandate fugitive particulate controls if the metal content is significant.

4.5 COKING OF PETROLEUM REFINERY WASTES

Delayed coking is a process used in some petroleum refineries to recover useful products from the heavy ends of the raw petroleum. In this process, the feed stream enters a fractionator where gas oil, gasoline, and lighter fractions are flashed off and recovered. The fractionator bottoms are combined with a recycle stream and heated to reaction temperatures of 480 to 580 °C in the coker heater. The vapor-liquid mixture from the heater then enters the coke drum, where the primary coking reaction takes place. The coke drum provides the proper residence time, pressure, and temperature for coking. In the coke drum, the vapor portion of the feed undergoes further cracking as it passes through the drum, and the liquid portion undergoes successive cracking and polymerization until it is converted to vapor and coke.[155] Coking units consist of at least two coke drums so that one can remain online while coke is removed from the other.

In removal of coke from the drum, steam is first injected into the drum to remove hydrocarbon vapors, which are cooled to form a steam-hydrocarbon mixture. This is followed by water injection to cool the coke and

allow removal. When the coke is cooled sufficiently, a high-pressure water jet is used to cut the coke into pieces that are then removed from the coke drum.

Coking is an alternative to the land treatment or landfilling of petroleum refinery hazardous wastes according to the requirements specified in the Federal Register. Coke produced from petroleum refinery hazardous wastes is exempt from regulation as a hazardous waste, if the waste is coked at the facility where the waste is generated. In addition, the coke cannot exhibit any of the characteristics of a hazardous waste.[156]

Refinery sludges can be introduced to a delayed coking operation in one of two ways. In one process, sludge is injected into the coker during the cool-down period. In that process, the water content of the sludge contributes to cooling the coke while organics are cracked into products or polymerized into coke. Sludge solids are immobilized inside the coke.[157] This process currently is used at several refineries. In the second process, sludge is introduced into the coker as a part of the feed stream by injecting it into the blowdown system where it is vaporized and recycled. In that process, the amount of sludge that can be added to the feed stream must not exceed some small percentage of the total feed, and the sludge must undergo extensive dewatering prior to entering the coking operation.[158] Only one refinery is known to use this operation.

No emission measurement data were found for coking operations; however, because the entire operation is enclosed, organic air emissions are estimated to be quite low. Some emissions would be expected from transfer, storage, and handling operations associated with coking. Most of these would be expected to come from the transportation of sludge from the point of generation to the coking operation and from storage of sludge at the coker. Although no definitive data are available to permit estimates of the emission reduction that would be achieved by processing refinery sludges through a coker rather than land treating, reductions approaching 100 percent are expected. Increased emissions from the coking operation as a result of introducing wastes into the feed stream are estimated to be negligible.

Coking is a possible control option at refineries that produce fuel-grade coke. At refineries that produce high-quality, electrode-grade coke, the quality degradation caused by sludge injection may be unacceptable. For refineries that do not have an existing coking operation, coking would not be a practical emission control alternative.

Coking may be a viable alternative for the disposition of hazardous refinery sludges for some facilities. Because this control option is available only at facilities that already have a coking operation and because organic air emissions from coking are estimated to be low, cross-media and secondary air impacts of adding waste to the coking operation are estimated to be negligible.

4.6 PROCESS MODIFICATIONS AND IMPROVED WORK PRACTICES

4.6.1 Submerged Loading

Loading emissions generated during waste transfer are the primary source of evaporative emissions from waste containers (e.g., tank trucks and drums) and tanks. It occurs when waste is transferred into a receiving container and displaces an equal volume of air saturated or nearly saturated with organics. The quantity of organic air emissions is a function of the loading method.

In splash loading, the influent pipe dispensing the waste is lowered only partially into the container or tank and waste is injected above the liquid level in the container or tank. Significant turbulence and vapor-liquid contact occur during splash loading, which results in high levels of vapor generation and loss. Control of loading emissions can be accomplished by using submerged loading. During submerged loading, the influent pipe opening is below the liquid surface level, which decreases turbulence and evaporation and eliminates liquid entrainment. The most recent use of a waste container or tank is also important in determining loading emissions. For example, if the most recent use of the container or tank was to store nonvolatile waste or if the container or tank has just been cleaned, it will contain vapor-free air. If the most recent use of the container was to store volatile waste and it has not been cleaned or vented

(dedicated service), the air in the container or tank will contain organic vapors that are expelled during the loading operation along with newly generated vapors. By changing from top-splash to submerged loading, organic air emissions can be reduced up to 65 percent when loading clean tank trucks and 59 percent when loading a dedicated normal service truck.[159] Similar emission control efficiencies should be achievable by submerged loading of drums and stationary tanks.

In estimating nationwide emissions, an emission reduction of 65 percent, as derived above from the procedures in Reference 159, is used for submerged loading for all waste types and vessel types. Selection of the 65-percent emission reduction was made on the assumption that, on average, tank trucks and containers are cleaned before filling.

Submerged loading of open area sources, such as surface impoundments or open-top tanks, is not considered a control technique unless it is used in conjunction with covers or enclosures over the source. If the loading is changed from above to below the liquid surface in the absence of covers or enclosures, organics that would have been emitted during filling are instead emitted quickly from the open liquid surface by wind blowing across the source. However, if the open-top tank is covered or if the impoundment is enclosed, then emissions may be generated from the displacement of vapor by liquid. In this case, submerged loading may reduce emissions as described above for stationary tanks and tank trucks and would provide additional control of organic air emissions. There are no cross-media or secondary environmental impacts associated with submerged loading.

4.6.2 Subsurface Injection

Subsurface injection is a land treatment practice in which waste is injected directly into the soil. The process could be used to apply wastes to a land treatment site in lieu of surface application. In subsurface injection, as opposed to surface application, there is no pooling of liquid on the soil surface and thus potentially less opportunity for the material to be emitted to the atmosphere. However, in a field study to evaluate the relative air emissions from land treatment plots using surface application and subsurface injection, no difference in emissions was evident.[160]

Therefore, subsurface injection is not currently being considered for air emission control.

4.6.3 Daily Earth Covers

Daily earth covers, as the name implies, consist of the daily application of an earthen barrier over an emission source. The technique often is used to control emissions from landfills. During normal operation of a landfill, waste is deposited at specified locations and then is spread and compacted with a bulldozer. If left exposed, the waste will continuously emit organics until the supply is exhausted. To limit these emissions, a layer of compacted earth usually 15 to 20 cm thick can be installed on top of the waste. Ideally, earth covers should be placed as soon as the waste has been spread and compacted.

Typically, earth covers are constructed of locally available soil and most probably soil that had been placed on a spoils pile during construction of the landfill. The permeability of the cover is determined by the size of the pores, the total porosity, and the extent to which the pore spaces are blocked by water. A dry, coarse-grained soil may be very inefficient as a vapor barrier, while a well-compacted, saturated, fine-grained soil may completely block organic air emissions.

Emission reductions achieved by an earth cover depend on the type of soil used, its moisture content, the degree of compaction achieved, and the thickness of the soil layer. Using an analytical emission model to estimate emissions through a 20-cm soil layer, calculated emissions changed by more than two orders of magnitude as soil moisture content was varied from near zero to saturation. In practice, emission reductions achieved by earth covers would vary depending on the impact of local climate conditions on soil moisture content.

4.6.4 Mechanical Mixers

Mechanical mixers are devices that can be used in the waste fixation process for mixing liquid wastes with fixatives such as portland cement, cement kiln dust, or lime flue dust. They can serve to replace traditional open pit fixation operations that currently are used at many TSDF. One type of mixer in current use is the pugmill.[161] In general, a pugmill is

shaped like a trough roughly 0.9 m wide and 3 m long (the size varies) and contains two counter-rotating shafts running the length of the unit. The shafts are fitted with paddles or cogs designed to agitate and mix the materials in the device while transporting them from one end of the trough (where the materials are introduced) to the other end (where the fixed waste exits). These mixers process wastes continuously, the throughput depending on the size and design of the mixer. Because they can be easily fitted with covers, emissions from these devices can be captured and controlled more easily than emissions from open fixation pits.

Potential emission sources associated with mechanical mixer waste fixation are the storage tank that receives incoming liquid wastes and sludges, the mechanical mixer, and the processed waste-receiving bin (a receptacle or area beneath the mixer for temporarily holding fixed waste as it leaves the mixer and from which the waste is transported to a wastepile or landfill). At mixer installations where fixed waste is deposited on a conveyor belt instead of into a bin, the conveyor belt is an additional potential emission source. No data were found that quantify the emission reduction achieved by replacing open pit fixation with enclosed mechanical mixers. However, capture of emissions from mechanical mixers should approach 100 percent because of the relatively small size of the mixers and the ease with which they can be sealed or enclosed (inspection and access hatches must be kept closed when the mixer is in use). If 100-percent capture is assumed, overall control efficiency is a function only of the efficiency of the control device added on to the vent, which, for activated carbon, would be 95 percent or greater (see Section 4.2.2). In estimating nationwide emissions, a control efficiency of 95 percent is used for mechanical mixers vented to a carbon adsorption unit.

If carbon canisters are used, then contaminated carbon disposal must be dealt with periodically. Fixed-bed carbon adsorber systems require steam generation and produce a contaminated condensate that can be fed into the waste fixation process for final disposal. If fixed-bed systems are used, secondary environmental impacts would be produced from fuel combustion required to produce steam for regenerating the activated carbon.

These impacts would consist of combustion products (e.g., NO_X, SO_X, CO) and would vary depending on the type of fuel used.

4.6.5 Housekeeping in Drum Storage Areas

Drum storage is the temporary holding of liquid, semisolid, or solid wastes until treatment and/or disposal can be undertaken. Drums can be stored on concrete pads that have a perimeter curb and gutter for secondary containment. Secondary containment is required at any drum storage area (40 CFR 264.175), and spilled or leaked waste and accumulated precipitation must be removed from the sump or collection area in as timely a manner as necessary to prevent overflow of the collection system.

Typically, drums are sealed and in good condition during storage; therefore, the potential for breathing emissions is assumed to be negligible. However, drums may rupture and leak hazardous wastes during storage or transfer. Management and technical practices not only cause spillage, they also determine what fraction is available for volatilization. Because RCRA requires that container storage areas be inspected weekly for container leaks and deterioration (40 CFR, 264.174), a 50-percent loss of the volatiles to the atmosphere from the spilled waste was selected for emission estimating purposes; the remaining 50 percent are recovered as a result of implementing RCRA spill response actions.

Two control options are considered appropriate for reducing emissions from drum storage: one option is to vent the existing enclosed drum storage areas through a fixed-bed carbon adsorption system (see Section 4.2.2 for more detail). The other control option is to use an open secondary containment area, conduct daily inspections and maintenance, and have a policy to clean up spills within 24 hours of discovery. This option is an adaptation of the proposed 1986 RCRA tank regulations (40 CFR 264.196). Leak detection of stored drums is accomplished by visual inspection on a daily basis. In case of a spill or leak, sorbent material is used to clean up the spillage within 24 h, or the spillage is collected in a collection sump for transfer to a drum for treatment or disposal within 24 h. This policy of daily inspection with cleanup within 24 h decreases the fraction of volatiles lost to the atmosphere. The magnitude

of the reduction will depend on operating practices, waste type, and volatiles concentration; however, no data are available that quantify the emission reduction achieved by this method. Because it is estimated that these housekeeping practices are already used at most TSDF, no credit for an emission reduction was included in the estimates of nationwide emissions.

4.7 CONTROL OF EQUIPMENT LEAK EMISSIONS FROM WASTE TRANSFER

Waste transfer operations often involve pumping waste through pipelines into a variety of waste management process units. This pumping creates the potential for equipment leak (fugitive) emissions from pump seals, valves, pressure-relief valves, sampling connections, and open-ended lines and flanges. Leaks from these types of equipment are generally random occurrences that are independent of temperature, pressure, and other process variables. However, these leaks do show a correlation with the vapor pressure of the material in the line. For example, monthly inspection data from the synthetic organic chemicals manufacturing industries (SOCMI) show that 8.8 percent of the seals on pumps handling light liquids have leaks and only 2.1 percent of the seals on pumps handling heavy liquids have leaks.[162] Light liquids are defined as those containing at least 20 percent by weight of organic compounds having a vapor pressure greater than 10 mm Hg.

An effective method for controlling fugitive emissions is to implement a routine leak detection and repair program (i.e., periodic inspection and maintenance). Leaks can be detected by individual component surveys, which may be carried out independently or may be a part of activities such as area (walkthrough) surveys, fixed-point monitoring, and visual inspection. Leaks can be repaired by adjusting the tightness of parts in pumps, valves, pressure-relief valves, closed-loop sampling, and capping or plugging open-ended lines or by replacing faulty devices. The use of portable organic vapor detection instruments during individual component surveys is considered to be the best method for identifying leaks of organics from valves and pump seals;[163] use of such instruments constitutes the only type of leak detection method for which a control efficiency has been quantified.

The control efficiency of individual component surveys depends on: (1) action level or leak definition, (2) monitoring interval or frequency, (3) achievable emission reduction of maintenance, and (4) interval between detection and repair of the leak. Background information developed by EPA to support standards for SOCMI fugitive emissions indicates that a monthly inspection and repair program of systems handling light liquid reduces fugitive emissions from pumps by 61 percent and from valves by 46 percent.[164] The study also shows that closed-loop sampling and capping open-ended lines provide 100 percent control of these emission sources. Considering the similarity between SOCMI sources and TSDF sources, these practices are expected to give equivalent reductions at TSDF. Nationwide emission reductions were estimated based on the above emission reductions along with the estimated relative numbers of pumps, valves, sampling connections, and open-ended lines in the waste management system. Combined, these control techniques provide weighted control efficiencies of 70 percent for systems handling light liquids and 78 percent for systems handling heavy liquids.

4.8 CROSS-MEDIA AND SECONDARY ENVIRONMENTAL IMPACTS

When emission controls described in this chapter are applied to an emission source, the controls themselves, in most cases, generate cross-media or secondary environmental impacts. Cross-media impacts result from any liquid waste, sludges, solid waste, or air emissions generated by the control device, and secondary environmental impacts result primarily from the generation of electricity or steam required by the controls. The preceding discussions of individual emission controls include an identification of the types of cross-media and secondary environmental impacts associated with each control. This section presents information that allows quantification of these impacts.

Cross-media and secondary environmental impacts can be in the form of air emissions, such as SO_x, NO_x, CO, and particulates; aqueous or organic liquid waste streams; or sludges or solids. Air emissions may be generated by any of the following:

- Burning of fuel oil or natural gas to generate steam for onsite carbon adsorber regeneration

- Incinerating recovered organics from separation processes or process vents

- Incinerating auxiliary (supplemental) fuel in an incineration process

- Generation of electricity.

Aqueous or organic liquid waste streams may consist of:

- Condensed steam used in activated carbon regeneration

- Decanted organics separated from condensed steam in activated carbon regeneration

- Exit streams (bottoms) from organic removal processes

- Effluent from liquid-phase activated carbon adsorption and steam stripping.

Sludges or solids may consist of:

- Spent activated carbon

- Carbon canisters

- Hazardous ash generated by incineration

- Ash produced by the combustion of coal to generate electricity

- Bottom residue from thin-film evaporation

- Sludge produced by flue gas scrubbers.

(Quantitative data to support this section are currently under development.)

4.9 SUMMARY OF CONTROLS SELECTED FOR DEVELOPMENT OF CONTROL STRATEGIES

This section summarizes the controls selected for further consideration in the formulation of control strategies for TSDF air emissions. (A control strategy is a combination of specific controls applied to specific TSDF emission sources resulting in an overall reduction in nationwide TSDF air emissions.) The development of control strategies and estimates of the nationwide emission, health risk, other environmental, and cost impacts of

strategies are discussed beginning in Chapter 5.0. Not all of the emission controls discussed in the previous sections of this chapter are considered practical means of controlling emissions from all of the emission sources identified in Chapter 3.0. Table 4-2 lists the TSDF emission sources and the types of emission controls that are used to formulate control strategies for reducing TSDF emissions. The control types are listed by TSDF process emission source. The organic removal/hazardous waste incineration controls operate on the wastes instead of being applied to a waste management process. The remainder of the list includes controls that may be applied directly to a waste management process. Table 4-3 shows the emission reduction efficiencies used in the nationwide impacts analysis for specific control options applied to specific emission sources. This table is a summary of the emission reduction efficiencies discussed in preceding sections and represents the values used in estimating nationwide impacts of control strategies.

Earlier in Section 4.2.1, the concept of generic control devices was introduced. Although the control types listed in Table 4-3 for the source category are typically applicable to the source category, there may be site-specific conditions that prevent the use of a particular control type at a particular facility. Where there are several choices of control type with equivalent levels of performance for a specific source category, presumably the facility operator would choose the lowest cost type to apply. In some cases, there are significant differences in the costs of control for similar performance levels, but factors such as waste incompatibility or source shape may prevent use of the least costly control.

For this reason, generic control devices have been defined for certain source categories in the process of estimating nationwide emission reductions and control costs. Table 4-4 lists the options of generic control devices for the source categories as used in the nationwide impacts estimates.

Selection of the percentage weightings for each option was made on the basis of engineering judgment, taking into account the application limitations of control options, relative costs, and limited information about

TABLE 4-2. EMISSION CONTROL OPTIONS USED FOR SELECTING TSDF CONTROL STRATEGIES[a]

Management process source category	Control options[b]			
	Suppression	Add-on	Organic-removal/HW incineration	Process modification/work practices
Quiescent surface impoundment[c]	X			
Storage or treatment	X	X		
Disposal		No direct controls; pretreat to remove organics or incinerate wastes[d]		
Dumpster storage	X			
Quiescent (storage or treatment) tank				
Uncovered	X			
	X	X		
Covered		X		
Waste fixation				
Pit	X	X		X
Enclosed mechanical mixer		X		
Aerated/agitated surface impoundment (treatment)	X	X		
Aerated/agitated uncovered tank (treatment)	X	X		
Land treatment		No direct controls; pretreat to remove organics, incinerate, or coke wastes[e]		
Active landfill	X			
Closed landfill	X			
Wastepile	X			

(continued)

TABLE 4-2 (continued)

| Management process source category | Control options[b] | | | |
	Suppression	Add-on	Organic-removal/HW incineration	Process modification/work practices
Equipment leaks				
Pumps, valves, and pressure-relief valves				X
Sampling connections				X
Open-ended lines				
Drum storage with enclosure[f]		X		
Drum and tank truck loading				X
Spills				X
Organic compound removal devices		X		
All TSDF process/emission sources[g]		X	X	

TSDF = Transfer, storage, and disposal facilities.
HW = Hazardous waste.

[a]The development of control strategies is discussed in Chapter 5.0.

[b]Emission control options are of four types; examples of each control type are given in Table 4-1. Specific control options evaluated in this study are identified in Table 4-3.

[c]Includes treatment impoundments that are dredged annually and that are thus exempt from land disposal restriction regulations.

[d]Disposal surface impoundments function via evaporation. Direct controls such as covers inhibit evaporation.

[e]Coking is a control option only at refineries that have an existing coking operation and that meet the conditions specified in a November 1985 *Federal Register* notice.[166]

[f]Drums and containers are stored in a building that can be vented to a control device.

[g]When a waste is pretreated to remove organics, is incinerated, or is processed through a coker, emissions from all TSDF emission sources are affected except those that precede the organic removal, incineration, or coking operation.

TABLE 4-3. EMISSION CONTROL EFFICIENCIES USED IN ESTIMATING NATIONWIDE IMPACTS OF CONTROL STRATEGIES

Management process source category	Control device	Waste form[b]	Effect on organic emissions,[a] %			
			Capture[c]	Suppression	Removal	Control
Quiescent surface impoundment[d]	Floating synthetic membrane	All	--	85	--	--
Storage or treatment	Air-supported structure vented to fixed-bed carbon adsorber[e]	All	100	95	--	--
Dumpster storage	Dumpster cover	All	--	99	--	--
Quiescent (storage or treatment) tank						
Uncovered	Fixed roof[f]	All	--	86.4-99.2	--	--
	Fixed roof with internal floating roof[f]	All	--	96.5-99.9	--	--
	Fixed roof vented to carbon canister[g] or existing combustion device	All	100	86.4-99.2	--	95
	Fixed roof vented to fixed-bed carbon adsorber[g]	All	100	99.3-99.96	--	--
Covered	Internal floating roof[f]	3,5,7	--	74-82	--	--
	Fixed-roof tank vented to carbon canister[g] or existing combustion device	All	--	--	--	95
	Fixed-roof tank vented to fixed-bed carbon adsorber[g]	All	100	95	--	--
Waste fixation						
Pit	Fixation with enclosed mechanical mixer with control device	All	100	--	--	95
Enclosed mechanical mixer	Fixation with enclosed mechanical mixer with control device	All	100	--	--	95
Aerated/agitated surface impoundment (treatment)	Air-supported structure vented to fixed-bed carbon adsorber[h]	All	100	95	--	--
Aerated/agitated uncovered tank (treatment)	Fixed roof vented to fixed-bed carbon adsorber	All	100	95	--	--
Land treatment	Waste coking	2	--	--	--	100
Closed landfill	30-mil HDPE cover	1	--	0	--	--
		2,3	--	99.7	--	--
		4,5,7	--	49.3	--	--

See notes at end of table.

TABLE 4-3 (continued)

Management process source category	Control device	Waste form[b]	Effect on organic emissions,[a] %			
			Capture[c]	Suppression	Removal	Control
Wastepile	100-mil HDPE cover	1	--	0	--	--
		2,3	--	99.9	--	--
		4,5,7	--	84.8	--	--
	30-mil HDPE cover	1	--	0	--	--
		2,3	--	99.7	--	--
		4,5,7	--	49.3	--	--
Equipment leaks Pumps, valves, and pressure-relief valves	Leak detection and repair	Light liquid	--	70	--	--
		Heavy liquid	--	78	--	--
Sampling connections	Closed-loop sampling					
Open-ended lines	Caps or plugs					
Drum storage with enclosure[i]	Carbon adsorber	--	--	--	--	95
Drum and tank truck loading	Submerged loading	All	--	65	--	--
Spills	Housekeeping	All	--	50	--	--
Organic compound removal devices	Existing control device[j]	--	--	--	--	95
	Catalytic incinerator	--	--	--	--	98
	Condenser	--	--	--	--	98.4-99.99[k]
	Thermal incinerator	--	--	--	--	98
	Carbon adsorber	--	--	--	--	95
All TSDF process/emission sources[l]	Organic removal and HW incineration					
	Constituent volatility					
	Air stripping	High	--	--	99.0	--
		Medium	--	--	13.7	--
		Low	--	--	1.0	--
	Steam stripping	High	--	--	99.999	--
		Medium	--	--	94.5	--
		Low	--	--	16.5	--
	Batch distillation	High	--	--	99.0	--
		Medium	--	--	18.0	--
		Low	--	--	6.0	--
	Thin-film evaporation	High	--	--	99.8	--
		Medium	--	--	65.9	--
		Low	--	--	20.7	--

See notes at end of table.

TABLE 4-3 (continued)

Management process source category	Control device	Waste form[b]	Effect on organic emissions,[a] %			
			Capture[c]	Suppression	Removal	Control
All TSDF process/emission sources[l] (con.)	Hazardous waste incineration	All	--	--	--	99.99
	Leak detection and repair, closed-loop sampling, and caps or plugs	Light liquid	--	70	--	--
		Heavy liquid	--	78	--	--

HDPE = High-density polyethylene.
TSDF = Transfer, storage, and disposal facilities.
HW = Hazardous waste.
-- = Not applicable.

[a]A control device may affect emissions in any of four 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; it may remove organics from the waste stream before the stream enters other waste management processes; or it may control emissions by destroying the organics or removing organics from a vent stream.

[b]Waste form identification:
   1 Organic-containing solid
   2 Aqueous sludge/slurry
   3 Dilute aqueous waste
   4 Organic liquid
   5 Organic sludge/slurry
   6 Miscellaneous
   7 Two-phase aqueous/organic.

[c]Capture efficiencies are based on application of the controls to the emission sources identified in Table 4-2.

[d]Includes treatment impoundments that are dredged annually and that are thus exempt from land disposal restriction regulations.

[e]Desorbed material is returned to impoundment.

[e]Efficiencies vary by compound volatility.

[f]The efficiency of a fixed-roof tank in suppressing emissions relative to an open tank varies depending on the characteristics of the waste and the operating parameters of the tank.

[g]A fixed roof applied to an open tank suppresses emissions by 86.4 to 99.2 percent. If the fixed roof is vented to a control device, the remaining emissions are reduced by 95 percent to give an overall emission reduction of 99.3 to 99.96 percent. If the control device is a fixed-bed carbon adsorber, desorbed material is returned to the tank so that the total emission reduction is by suppression. If the control device is a carbon canister or existing combustion device, the overall emission reduction consists of 86.4 to 99.2 percent suppression and 95 percent control.

[h]Desorbed material is returned to impoundment.

[i]Drums and containers are stored in a building that can be vented to a control device.

[j]An existing control device is defined as one of the add-on controls described in this chapter to which the source may be vented.

[k]Efficiencies vary by compound volatility.

[l]When a waste is pretreated to remove organics, or is incinerated, emissions from all TSDF emission sources are affected except those that precede the organic removal, or incineration.

TABLE 4-4. GENERIC CONTROL DEVICE DEFINITIONS[a]

Management process source category	Control type	Percentage weighting	Control options
Quiescent (storage or treatment) tank			
Uncovered	Suppression plus suppression or	50	Fixed roof plus internal floating roof
	suppression plus add-on	25	Fixed roof plus venting to carbon canister or fixed-bed carbon adsorber
		25	Fixed roof plus venting to existing control device
Covered	Suppression or add-on	50	Internal floating roof
		25	Vent to carbon canister or fixed-bed carbon adsorber
		25	Vent to existing control device
Waste fixation	Add-on	70	Replace pit with mechanical mixer vented to fixed-bed carbon adsorber
		30	Vent existing mechanical mixer to fixed-bed carbon adsorber

[a]This table defines the combinations of control options used to estimate nationwide emission reductions and control costs for the listed source category and control type. Potentially applicable control options are listed in Table 4-2.

[b]Percentage weightings show the percentages of each control option emission reduction and cost used to define overall emission reductions and costs for the particular combination of source category and control type.

current industry practice. For example, venting a tank to an existing control device onsite is generally less expensive than using an internal floating roof or venting to carbon canisters. However, not all TSDF have an existing control device suitable to receive the tank vent stream. Depending on number of tank turnovers and organic content of the waste, an internal floating roof will be less expensive than venting to a carbon canister. However, some wastes are not compatible with roof seal materials, so the internal floating roof is not always applicable either. With a low number of tank turnovers and low concentrations of low-volatility organics, carbon canisters can be cost-competitive with internal floating roofs (details of estimated emission reductions and control costs for the tank model units storing or treating model wastes are given in Appendix C). The percentage weightings in Table 4-4 for tank controls have been selected after considering the above factors.

In the case of waste fixation, visits to a number of waste fixation facilities have shown that fixation is done both in fixation pits and in mechanical mixers. No survey data are available, but pits are believed to outnumber the mixer operations. The 70:30 ratio of pits to mixers has been selected as a best estimate of current status.

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5.0 CONTROL STRATEGIES

The purpose of this chapter is to present the general concept of con-
trol strategies and to identify specific example control strategies. The
example strategies will be used in later chapters to illustrate how impacts
are calculated for each strategy considered as a possible basis for air
emission standards to be proposed for treatment, storage, and disposal
facilities (TSDF) under Resource, Conservation, and Recovery Act (RCRA)
Section 3004(n). In addition, this chapter will discuss specific impacts
to be estimated and will identify the "baseline" against which the nation-
wide impacts of control strategies will be measured.

As will be shown, the number of potential control strategies for TSDF
is large. Consequently, this chapter presents only example control strate-
gies to show how strategies are developed and evaluated. It should be
emphasized that the examples presented in this chapter will not necessarily
be the basis for the proposed standards. The strategies evaluated prior to
proposal of the standards, and the impacts of those strategies, are pre-
sented separately in the project docket. The strategy selected as the
basis for the proposed standards, and the factors leading to the selection
of that strategy, will be discussed in the preamble to the proposed stand-
ards published in the Federal Register.

5.1 CONTROL STRATEGY CONCEPT

As discussed in Chapters 3.0 and 4.0, there are a variety of sources
of organic emissions at TSDF and several types of emission controls that
can be applied to many of these sources. The term "control strategy," as
used here, refers to a unique combination of emission sources, emission
controls, and action level cutoffs (see Section 5.1.1.3) for applying the
controls. Different strategies are developed and evaluated to estimate the
impacts of potential regulations. It is important to recognize, however,

that although a control strategy identifies specific emission controls to be applied to TSDF sources, a regulation written to implement the strategy may be in terms of performance standards that allow equivalent, or more effective, controls for compliance. The possible combinations of sources, controls, action level cutoffs, and approaches to selecting strategies for evaluation from the many combinations possible are discussed in the following sections.

5.1.1 Combinations of Emission Sources, Controls, and Cutoffs

5.1.1.1 Emission Sources. TSDF emission source categories are shown in Table 5-1. Hazardous waste management processes with similar emission characteristics and potential emission controls are grouped together (e.g., aerated tanks and aerated impoundments are combined into one source category). Landfills, wastepiles, and land treatment are shown grouped together under the category of "Land Disposal Units." This is because hazardous wastes entering these types of waste management units are covered by the land disposal restrictions (LDR), which require treatment of a waste with best demonstrated available technology (BDAT) before it is placed in one of these units. It is presumed that this pretreatment will decrease the organic air emission potential of landfills, wastepiles, and land treatment. This presumption will be reviewed after all requirements under the land disposal restriction program are promulgated.

Surface impoundments are also covered by the LDR, but are exempt from LDR requirements under certain conditions. Those impoundments not covered by the LDR would continue to have significant potential air emissions and, therefore, additional controls for surface impoundments should be considered under RCRA Section 3004(n). More information on the land disposal restrictions is presented in a discussion of the baseline in Section 5.3.2.

Control of organic emissions from equipment leaks and process vents at TSDF is required by a separate rulemaking under RCRA Section 3004(n) proposed on February 5, 1987 (52 FR 3748). The proposed rule requires 95 percent control of process vent emissions and a leak detection and repair program for TSDF sources handling hazardous waste containing greater than 10 percent organics.

TABLE 5-1. TSDF EMISSION SOURCE CATEGORIES

Source category
Storage tanks
Quiescent treatment tanks
Quiescent impoundments (storage or treatment)
Aerated or agitated tanks or impoundments
Drum storage
Loading
Dumpster storage
Waste fixation
Equipment leaks[a]
Process vents[a]
Land disposal units: Landfills, wastepiles, and land treatment[b]

TSDF = Treatment, storage, and disposal facilities.

[a]These sources are covered by TSDF air standards for process vents and fugitive emissions, proposed February 5, 1987 (52 FR 3748).

[b]All hazardous wastes placed in these sources must meet pretreatment requirements of the land disposal restrictions.

5.1.1.2 <u>Controls</u>. In Chapter 4.0, four basic categories of controls are mentioned. Two of those categories--suppression or containment and organic removal--provide distinctly different bases for the formulation of control strategies as discussed below.

As discussed in Chapter 4.0, Section 4.1, suppression or containment controls prevent or reduce the rate of emissions from processes to which they are applied. Given that TSDF are usually comprised of a sequence of waste management processes, it follows that suppression or containment controls must be applied to each waste management process in the sequence to be effective. Otherwise, the suppression or containment functions only to transfer the air emissions to a point farther downstream in the facility. Ultimately, the wastes must be sent to disposal. Unless disposal is by deep well injection or the organics are destroyed (e.g., incineration), the potential for air emissions will continue to exist.

The organic removal processes (discussed in Chapter 4.0, Section 4.3) function as indicated by the name. Waste streams are treated to remove the organics from the stream, thus reducing the potential for air emissions from any process farther downstream. Organic removal processes could be placed at almost any point in the waste management sequence, except that some amount of waste storage and waste preparation (e.g., solids separation) may be necessary upstream of organic removal. Although the organic removal process might be placed in front of any of many steps in the waste management sequence, generally it would be most effective if placed as far upstream in the waste management sequence as possible, thus reducing the air emission potential from all the processing steps that follow. The organics that are removed from the waste streams may be recovered/recycled, burned as an energy source, or incinerated to prevent organic air emissions.

Control strategies based entirely on either suppression controls or organic removal are not possible because these controls cannot be adapted to all TSDF emission sources. However, strategies can be formed that depend predominantly on one or the other of these control types.

5.1.1.3 <u>Cutoffs</u>. Rather than apply emission controls to waste management processes without regard to the emission potential of the wastes

managed, a control strategy may include an action, or "cutoff," level above which controls must be applied. Cutoffs can be used as a mechanism for prioritizing emission sources within a waste management facility for control and for excluding sources that have low emission potential. Cutoffs can be expressed in several formats (e.g., in terms of volume throughput, capacity, or measured or calculated emissions). A cutoff format easily applied and directly related to emission potential for most TSDF sources is waste volatile organic content.

A cutoff based on waste volatile organic content, as measured by an appropriate test method, could be applied in either of two ways. One way would be to establish a single cutoff level, applied to waste as it is received at a facility (plant), that would dictate what emission controls are required on all waste management processes within that facility. A second way would be to develop separate, source-specific cutoff levels for each waste management process type. This second approach would provide more flexibility in applying controls but would require waste testing at more locations.

5.1.1.4 <u>Possible Combinations of Sources, Controls, and Cutoffs</u>. Table 5-2 presents some potential combinations of TSDF emission sources, emission controls, and cutoff levels to illustrate the large number of possible control strategies. Although the number of emission source/control combinations is fixed, any level could be chosen for a cutoff making the number of emission source/control/ cutoff combinations, and hence the number of control strategies possible, unlimited.

5.1.2 <u>Approaches to Selecting Control Strategies for Evaluation</u>

As demonstrated in the previous section, the number of possible combinations of TSDF emission sources, controls, and action level cutoffs (control strategies) is large. It is not possible to evaluate every combination in detail. Several approaches will be taken to select a limited number of control strategies for detailed evaluation from among the many possible strategies. Some of these are discussed below.

- <u>Identify Efficient Strategies</u>. The mandate of RCRA Section 3004(n) is to develop standards as necessary to protect human health and the environment. With the many possible combinations of emission sources, controls, and cutoffs, it

TABLE 5-2. POTENTIAL SOURCE/CONTROL/CUTOFF COMBINATIONS

TSDF emission source category	Controls[a]	Example cutoffs, (in ppm except as noted)[b]
Storage tanks	0, 1, 2	500 for level 1 controls 1.5 psia for level 2 controls
Quiescent treatment tanks	0, 1, 2, 3	500 for level 1 controls 1.5 psia for level 2 controls
Quiescent treatment impoundments	0, 1, 2, 3	500
Aerated tanks or impoundments	0, 2, 3	500
Drum storage	0, 2	500
Loading	0, 1	500
Dumpster storage	0, 1	500
Waste fixation	0, 2, 3	500
Equipment leaks	1 (Required by Proposed Rule for TSDF Equipment Leaks and Vents)	100,000
Process vents	2	
Land disposal units[c]	3 (Required by land disposal restrictions)	NA

TSDF = Treatment, storage, and disposal facilities.
NA - Not applicable.

[a]Key to controls:
    0 = No additional control
    1 = Suppression type controls such as covers
    2 = Venting air emissions to controls
    3 = VO removal or pretreatment type controls.

[a]Example cutoffs are based on volatile organic content of waste in parts per million, except as noted for storage tank level 2 controls, which are based on vapor pressure in the tank headspace. The examples are also based on measurement of the volatile organic content as the waste enters the TSDF. Alternatively, different cutoffs could be set for each waste management process to determine whether controls are required for each process.

[c]Includes certain surface impoundments, landfills, wastepiles, and land treatment.

is likely that many strategies will achieve comparable levels of health and environmental protection, but at different costs. As a first step in selecting strategies for detailed evaluation, the group of strategies that are most efficient in meeting health risk and environmental protection levels will be identified. This will eliminate higher cost strategies that do not achieve additional health and environmental protection for the added cost. It will also avoid overstating the cost of achieving a particular level of protection.

- Focus on Desired Results. Another approach will be to focus on possible desired results of applying strategies. For example, a desired result might be to reduce individual health risk to a certain "target" level. Similarly, a desired result might be to reduce another measure of health risk, such as cancer incidence, to a certain level.

- Best Technology. In contrast to focusing on desired results, several strategies will be selected based on the best demonstrated control technologies available for TSDF emission sources. Strategies that would require best technology for all TSDF sources, as well as strategies that would apply best technology to the major emitting TSDF sources, will be evaluated.

- Maximize Net Benefits. The monetary value of benefits yielded by control strategies, as well as control costs, can be estimated. Strategies that maximize net benefits can be selected for evaluation.

5.2 EXAMPLE CONTROL STRATEGIES

Two example control strategies were selected for use in later chapters to illustrate how the impacts of TSDF control strategies are estimated. These two strategies are shown in Table 5-3. They are presented for illustration purposes only and will not necessarily be the basis for proposed standards.

Example control strategy I is based primarily on the use of add-on emission controls applied to individual emission sources. In this example, if wastes containing more than 500 ppm of volatile organics (VO) are handled at a TSDF, quiescent impoundments and aerated tanks or impoundments would be covered or enclosed and vented to a control device to reduce organic emissions by 95 percent. Storage tanks and quiescent treatment tanks would be covered if the volatile organic content of the stored waste

TABLE 5-3. EXAMPLE TSDF AIR EMISSION CONTROL STRATEGIES[a]

Source category	Strategy I (applied when VO > 500 ppm)[b]	Strategy II (applied when VO > 500 ppm)[b]
Storage tanks	Cover, vent to control[c]	Cover, vent to control[c]
Quiescent treatment tanks	Cover, vent to control[c]	Organic removal
Quiescent impoundments (storage or treatment)	Cover, vent to control	Organic removal
Aerated or agitated tanks or impoundments	Cover, vent to control	Organic removal
Drum storage	No control on existing enclosure	Enclosure vented to control
Loading	Submerged loading	Submerged loading
Dumpster storage	Cover	Cover
Waste fixation	No control	Organic removal
- - - - - - - - - - - - - - -	- - - - - - - - - - - - - - -	- - - - - - - - - - - - - - -
Equipment leaks	Leak detection and repair[d]	Leak detection and repair[d]
Process vents	95% control[d]	95% control[d]
- - - - - - - - - - - - - - -	- - - - - - - - - - - - - - -	- - - - - - - - - - - - - - -
Land disposal sources[e]	Pretreatment as required by land disposal restrictions	Pretreatment as required by land disposal restrictions

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

[a]The strategies presented in this table are for use in illustrating how impacts associated with controls are calculated in later chapters. They will not necessarily be the basis for developing standards for proposal.

[b]Cutoff is based on volatile organic content of waste entering the facility as measured by a test method, except as noted for covered storage and quiescent treatment tanks. If volatile organic content of waste is above cutoff, then controls are required for all sources as shown.

[c]Storage and quiescent treatment tanks must be covered when volatile organic content of waste is above 500 ppm. Emissions from covered tanks must be vented to a control device when the waste in the tank has a true vapor pressure equal to or greater than 1.5 psia.

[d]Required by TSDF air standards for equipment leaks and process vents.

[e]Landfills, wastepiles, and land treatment.

is greater than 500 ppm. Covered storage and quiescent treatment tanks would be vented to an emission control device if the vapor pressure of the waste in the tank exceeds 1.5 psia. Dumpsters would be covered under example strategy I, and no controls would be applied to drum storage areas or waste fixation operations. Loading operations would be controlled by using submerged loading. Controls for process vents and equipment leaks would be as required by the proposed rules for TSDF equipment leaks and process vents, and emissions from landfills, wastepiles, and land treatment operation would be reduced under the land disposal restrictions.

Example strategy II is based primarily on the use of organic removal to reduce organic emissions from sources where it is applicable. In example strategy II, organic removal would be applied to wastes entering quiescent treatment tanks, quiescent impoundments, aerated or agitated tanks or impoundments, and waste fixation when the volatile organic content of the waste exceeds 500 ppm. Controls on the remaining sources would be as in example strategy I.

5.3 IMPACTS TO BE ESTIMATED FOR CONTROL STRATEGIES

The nationwide impacts that will be estimated for control strategies selected for detailed evaluation and the baseline to which the impacts of strategies will be compared are discussed below.

5.3.1 List of Nationwide Impacts to be Estimated

Implementation of any of the possible control strategies for TSDF air emissions would have a wide range of impacts. Some impacts, such as emission reduction, reduction in health risk, and cost of controls can be estimated, although with varying degrees of certainty. Other impacts of control strategies, such as ease of implementation, are difficult to quantify but are important to consider qualitatively nonetheless.

For example, organic emissions may contribute to the formation of ozone in the lower atmosphere (tropospheric ozone) or the depletion of ozone in the upper atmosphere (stratospheric ozone). Tropospheric ozone can adversely affect human health and the environment. Stratospheric ozone is essential to protecting the earth from the sun's ultraviolet radiation. A reduction in nationwide organic emissions could have a beneficial impact

on both tropospheric and stratospheric ozone, but because of the complexity of pollutant transport and ozone formation in the atmosphere, this impact is not easily quantified.

To ensure that the consequences of adopting control strategies can be anticipated as fully as possible, a wide range of nationwide impacts will be evaluated for control strategies considered as the possible basis for standards to be proposed under RCRA Section 3004(n). The impacts to be evaluated are listed in Table 5-4.

5.3.2 Baseline for Nationwide Impacts Estimates

The baseline provides a perspective from which the impacts of adopting control strategies can be evaluated. Chapter 3 of this document presents nationwide uncontrolled TSDF organic emissions; i.e., emissions with current existing controls and before the adoption of additional nationwide control requirements. However, there are regulations that affect TSDF air emissions that are, or will be, in place when the RCRA 3004(n) standards being developed in this rulemaking are promulgated. The baseline against which the potential impacts of the 3004(n) standards are measured should reflect these other regulatory requirements if they affect TSDF nationwide.

Federal regulatory requirements that affect TSDF nationwide include the land disposal restrictions (proposed and promulgated under RCRA Section 3004(m)) and TSDF air standards for process vents and fugitive emissions (proposed February 5, 1987, under RCRA Section 3004(n)). There are other Federal requirements applicable to TSDF, such as the RCRA Corrective Action Program (implemented under RCRA Section 3004(u)), but these are site-specific rather than nationwide control requirements.

Also, there are standards that apply to TSDF emission sources at the State level. However, these are limited and vary widely from State to State. A survey of State programs indicated that 12 States have established generic volatile organic compounds (VOC) standards that might affect TSDF emission sources. Thirty States have standards applicable to storage tanks, 17 States have standards for terminal loading, and 9 States have standards for hazardous waste landfills. For those States that do have standards, there are differences in how VOC is defined, making it difficult to compare requirements from State to State.

TABLE 5-4. NATIONWIDE IMPACTS TO BE ESTIMATED FOR CONTROL STRATEGIES

Emissions of volatile organics

Cancer incidence

Maximum individual cancer risk

Cross-media impacts

Capital and annual cost

Cost effectiveness

Cost effectiveness with benefit credit for volatile organics
emission reduction

Economic impacts

Ease of implementation

After the review of Federal and State standards applicable to TSDF, it was concluded that the baseline for the RCRA Section 3004(n) standards under development should reflect the impacts of the land disposal restrictions and the TSDF air standards for process vents and equipment leaks. Due to the limited applicability and lack of uniformity in State standards, they should not be included in the baseline.

More information on how the impacts of the land disposal restrictions and the TSDF process vent and equipment leak standards will be simulated in the baseline is presented below.

5.3.2.1 Land Disposal Restrictions. The Hazardous and Solid Waste Amendments (HSWA) of 1984 mandate a number of actions that EPA must take to reduce the threat of hazardous waste to human health and the environment. These actions include restricting hazardous wastes from land disposal. The EPA is currently developing regulations (referred to as land disposal restrictions) that will require that hazardous wastes be treated to reduce concentrations of specific chemicals or hazardous properties before the waste may be placed in a land disposal unit. The affected land disposal units include surface impoundments, wastepiles, landfills, and land treatment operations. Surface impoundments used for treatment of hazardous wastes are exempt from the land disposal restrictions if treatment residues are removed annually. The waste treatment technologies required to reduce chemical concentrations before land disposal are referred to as best demonstrated available technologies (BDAT). The restrictions express BDAT as a performance standard that requires wastes to be treated before entering a land disposal unit (to reduce the waste's toxicity or mobility). The wastes must be treated to levels that can be achieved by use of the best technologies commercially available.

The EPA is proposing and promulgating the land disposal restrictions in stages, with the final stage scheduled for promulgation in 1990. The first set of land disposal restrictions, for certain dioxins and solvent-containing hazardous wastes, was promulgated on November 7, 1986 (51 FR 40572). The second set of restrictions, the "California list," was promulgated on July 8, 1987 (52 FR 25760).

The standards for air emissions from TSDF being developed under Section 3004(n) in the current rulemaking are scheduled for promulgation in 1990, when the land disposal restrictions should be fully in place. Therefore, the land disposal restrictions are considered a part of the baseline against which the potential impacts of the 3004(n) standards are measured.

To simulate the impacts on TSDF air emissions from the land disposal restrictions, the following presumptions are made concerning the manner in which TSDF will respond to the restrictions:[1]

- All wastes currently land-treated (except organic-containing solids) will be incinerated. Solids will be fixated.

- All organic liquids and sludge/slurries that are currently sent to landfills and wastepiles will be incinerated or steam-stripped.

- All dilute aqueous liquids and aqueous sludge/slurries are fixated and landfilled.

- All surface impoundments will be converted to uncovered tanks.

Because the complete requirements of the land disposal restrictions have not yet been promulgated, the above presumptions may not be valid for all TSDF. However, on a nationwide basis, it is likely that they represent the general or average response of the hazardous waste management industry. Therefore, it is reasonable to include them in the baseline against which the nationwide impacts of potential air standards under RCRA Section 3004(n) are evaluated.

5.3.2.2 TSDF Air Standards for Equipment Leaks and Process Vent Control. On February 5, 1987, the EPA proposed RCRA air emission standards for volatile organics control at TSDF. These standards are intended to be an "accelerated" portion of the RCRA 3004(n) air standards. The proposed standards apply to new and existing facilities and pertain to both process and equipment leak air emissions. Sources of process emissions include process condenser vents, and distillate receivers, surge control vessels, product separators, and hot wells, if process emissions are vented through these vessels. Equipment leak sources include pumps, valves, pressure-relief devices, compressors, open-ended lines, and sampling connections. These standards will apply to hazardous wastes containing greater than

10 percent organics. Specific requirements include reduction of process vent emissions to less than 1.4 kg/h (3 lb/h) and 2.8 Mg/yr (3.1 tons/yr) or reduction of facility process vent emissions by 95 percent; and a leak detection and repair program for equipment leaks.

To simulate the impact of the accelerated rule on the baseline, all process vents and equipment leak emissions at facilities handling wastes containing greater than 10 percent organics will be controlled as part of the baseline.

5.4 REFERENCE

1. Industrial Economics, Inc., and ICF Incorporated. Regulatory Analysis of Proposed Restrictions on Land Disposal of Hazardous Wastes. Prepared for U.S. Environmental Protection Agency. Washington, DC. December 1985. p. 4-20 through 4-22 and exhibits.

6.0 NATIONAL ORGANIC EMISSIONS AND HEALTH RISK IMPACTS

The nationwide organic air emission and health risk impacts associated with each of the two treatment, storage, and disposal facility (TSDF) example control strategies identified in Chapter 5.0 are discussed in this chapter. The primary emphasis of Chapter 6.0 is to present the approach for assessing these impacts by using the example control strategies as a guide for discussion and presentation. Both beneficial and adverse environmental impacts are assessed. Table 6-1 summarizes these nationwide impacts; presented are the nationwide estimates of TSDF organic emissions, cancer incidence, and maximum lifetime risk for the two example control strategies as well as the uncontrolled and baseline scenarios. Comparisons to the baseline situation are also made to provide a relative measure of the effectiveness of or degree of control required under the two example strategies. More detailed information on the emissions and health risks associated with implementation of the example control strategies are provided in Sections 6.1 and 6.2. The nationwide emission reduction for each example control strategy is tabulated in Section 6.1. Impacts on human health, assessed as cancer incidence and maximum lifetime risk of contracting cancer, are presented in Section 6.2. Impacts on water quality, solid waste, energy, and other environmental concerns are under development and will be presented in Section 3.6 at a later date.

6.1 ORGANIC EMISSION IMPACTS

This section presents the nationwide impacts on TSDF organic air emissions for two example control strategies and includes a description of how emissions under the uncontrolled, baseline, and controlled scenarios were estimated. A tabular presentation of the estimated emission reductions from affected waste management units is also included. As discussed in Chapter 5.0, the baseline case assumes that Resource Conservation and

TABLE 6-1. SUMMARY OF NATIONWIDE ORGANIC EMISSIONS AND HEALTH RISK IMPACTS FOR
UNCONTROLLED, BASELINE, AND TWO EXAMPLE CONTROL STRATEGIES[a]

Control case	Emissions, 10^3 Mg/yr[b]	Emission reduction from baseline, 10^3 Mg/yr	Percent reduction, %	Cancer incidence,[c] incidence/yr	Incidence reduction from baseline incidence/yr	Maximum lifetime risk, MLR
Uncontrolled	1,810	--	--	130	--	1×10^{-2}
Baseline	1,835	--	--	135	--	1×10^{-2}
Example control strategy I[d]	364	1,471	80.2	21	114	4×10^{-4}
Example control strategy II[e]	349	1,486	81.0	15	120	5×10^{-4}

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

[a]With TSDF proposed air standards (for process vents and equipment leaks) and land disposal restrictions in place.

[b]Refer to Table 6-2 for nationwide emissions by source.

[c]Refer to Table 6-3 for nationwide cancer incidence by source.

[d]Example control strategy I applies to wastes containing greater than 500 ppm of organics. It entails covers and controls for tanks and impoundments, submerged loading of drums, and covers for dumpsters. For covered storage and quiescent treatment tanks, venting to a control device is required if the vapor pressure of the waste in the tank exceeds 1.5 psia.

[e]Example control strategy II applies to wastes containing greater than 500 ppm of organics. It entails introducing organics removal processes before treatment tanks, storage or treatment impoundments, and waste fixation processes; covers and controls for storage tanks as in example strategy I; enclosure and control of drum storage areas; submerged loading of drums; and covers for dumpsters.

Recovery Act (RCRA) land disposal restrictions and the 1987 proposed TSDF air emission standards (52 FR 3748) are in effect. Example strategies I and II represent two potential "controlled" cases. Data are presented for these three scenarios to allow comparison of the impacts of the example control strategies in relation to current and 1987 proposed standards on TSDF air emissions nationwide.

Chapter 3.0 of this document, "Industry Description and Air Emissions," provides nationwide estimates of uncontrolled emissions by TSDF management process. Nationwide emissions were computed using the computerized Source Assessment Model (SAM) by first identifying all process source categories listed in the Industry Profile (described in Appendix D.2.1). Once these categories were identified, their emissions were calculated by multiplying the organic quantity of each waste stream by an emission factor specific to the particular management process and the wastes being processed (see Appendix D, Section D.2.4.1). Emissions per process per TSDF then were summed to yield a nationwide uncontrolled emission estimate.

To calculate the quantity of emissions reduced by applying organic emission controls, the control technologies described in Chapter 4.0 were applied to the appropriate waste management processes (source category) as required by one of two example control strategies:

- Example control strategy I applies to wastes containing greater than 500 ppm of organics. It entails covers and controls for tanks and impoundments, submerged loading of drums, and covers for dumpsters. For covered storage and quiescent treatment tanks, venting to a control device is required only if the vapor pressure of the waste in the tank exceeds 1.5 psia.

- Example control strategy II also applies to wastes containing greater than 500 ppm of organics. It entails introducing organic removal processes before treatment tanks, storage or treatment impoundments, and waste fixation processes; covers and controls for storage tanks (with control devices for covered tanks required only if the vapor pressure of the stored waste exceeds 1.5 psia); control of enclosed drum storage areas; submerged loading of drums; and covers for dumpsters.

The magnitude of nationwide organic emissions associated with each example strategy was calculated using the SAM. In short, this consisted of adjusting the uncontrolled and baseline emissions by the control efficiency of the control technology required under each particular strategy, for each

TSDF process stream at each facility nationwide. Summation of results provides an estimate of emissions per control strategy. Table 6-2 presents the nationwide results by emission source and the emission reductions resulting from implementation of each control strategy by source category. Because the specific design and operating characteristics of each waste management process are not widely available, nationwide distributions of process design and operating parameters were used in estimating TSDF emissions. Therefore, it is appropriate that nationwide TSDF emissions and impacts are used in the comparison of the various control options and strategies. As noted in Chapter 3.0, the estimation of TSDF emissions in this document involved the use of the TSDF air emission models as presented in the March 1987 draft of the air emission models report rather than the December 1987 version of the report.

Nationwide uncontrolled emissions were estimated at about 1.81 million Mg/yr; baseline emissions were 1.83 million Mg/yr. Storage tanks are the largest uncontrolled emitters nationwide under these two scenarios. Process vents from organic removal devices have zero baseline emissions because these processes are not considered to be operating uncontrolled; that is, for process vents it is assumed that emissions are controlled under Federal regulations currently in effect.

Emission reductions from baseline for the two strategies range from 1.486 million Mg/yr (strategy II) to 1.471 million Mg/yr (strategy I). Control devices for tank storage yield the highest emission reductions in strategies I and II (99.7 and 99.3 percent, respectively). Some sources such as waste fixation processes show an increase in emissions when a control strategy is applied. These increases occur because (1) emissions are suppressed from upstream controlled sources (i.e., the waste stream retains the organics that would have previously been emitted, which results in an increase in organics at the source of interest), and (2) when controls are applied, new emission sources are created such as pumps and valves (i.e., equipment leaks).

6.2 HUMAN HEALTH RISKS

Health risks posed by exposure to TSDF air emissions are presented in this section in three forms: annual cancer incidence (incidents per year nationwide resulting from exposure to TSDF air emissions), maximum lifetime risk (the highest risk of contracting cancer that any individual could

TABLE 6-2. NATIONWIDE TSDF EMISSIONS AND EMISSION REDUCTION FOR THE UNCONTROLLED, BASELINE,
AND TWO EXAMPLE CONTROL STRATEGIES[a]

Source category	Uncontrolled emissions, 10^3 Mg/yr	Baseline emissions,[b] 10^3 Mg/yr	Example control strategy I[c]			Example control strategy II[d]		
			Emissions, 10^3 Mg/yr	Emission reduction from baseline, 10^3 Mg/yr	Percent reduction, %	Emissions, 10^3 Mg/yr	Emission reduction from baseline, 10^3 Mg/yr	Percent reduction, %
Drum storage	0.19	0.19	0.19	0	0	0.013	0.18	95
Dumpster storage	78	78	2.1	76	97	2.1	76	97
Storage tanks	756	758	3.9	754	99	7.2	751	99
Quiescent surface impoundments	209	208	42	167	80	64	145	69
Quiescent treatment tanks	48	48	15	33	69	18	30	63
Aerated tanks and surface impoundments	515	515	27	488	95	195	320	62
Wastepiles	0.13	0.033	0.033	0	0	0.004	0.029	88
Landfills	40	2.1	3.8	-1.7[e]	-	0.60	1.5	71
Waste fixation process	2.1	177	220	-44[e]	-	9.8	167	94
Incineration[f]	0.89	1.1	1.1	0	0	0.95	-0.15[e]	-
Land treatment	73	0	0	0	0	0	0	0
Other treatment[g]	0	0	0	0	0	3.0	-3[e]	-
Spills	0.43	0.42	0.43	-0.01[e]	-	0.49	-0.07[e]	-
Loading	6.8	6.8	5.1	1.7	25	3.9	2.9	43
Equipment leaks	80	40.3	43	-2.7[e]	-	44	-3.7[e]	-
TOTAL[h]	1,810	1,835	364	1,471	80.2	349	1,486	81.0

See notes at end of table.

TABLE 6-2 (continued)

TSDF = Treatment, storage, and disposal facility.

- = No reduction achieved.

[a]Estimated values for each source category should not be used or viewed independently because some control technologies may suppress emissions or reduce emissions (e.g., organic removal processes) that will impact sources downstream.

[b]With TSDF proposed air standards (for process vents and equipment leaks) and land disposal restrictions in place.

[c]Example control strategy I applies to wastes containing greater than 500 ppm of organics. It entails covers and controls for tanks and impoundments, submerged loading of drums, and covers for dumpsters. For covered storage and quiescent treatment tanks, venting to a control device is required if the vapor pressure of the waste in the tank exceeds 1.5 psia.

[d]Example control strategy II applies to wastes containing greater than 500 ppm of organics. It entails introducing organics removal processes before treatment tanks, storage or treatment impoundments, and waste fixation processes; covers and controls for storage tanks as in example strategy I; enclosure and control of drum storage areas; submerged loading of drums; and covers for dumpsters.

[e]Negative numbers mean an increase in emissions. This is due to emissions suppressed from upstream controlled sources, increasing organics loading at the source of interest, and the creation of new emission sources such as pumps and valves (i.e., equipment leaks) when controls are applied.

[f]Uncontrolled incinerator emissions include emissions from wastes that are routinely incinerated with stack exhaust gas emission controls. These sources are currently regulated under 40 CFR 264 Subpart 0. The uncontrolled emission scenario does not include wastes that are or would be incinerated as a result of implementing the RCRA land disposal restrictions. The baseline and two example strategies do, however, account for the incinerator emission resulting from the land disposal restrictions. The emission scenarios are explained in Chapter 5.0.

[g]Other treatment includes processes such as stream stripping that are typically used to remove organics from wastes. For the uncontrolled emission case, these emissions are built into the tank treatment category because of similarities in emission characteristics.

[h]The sum of each column of data does not equal the total value because of rounding.

have from exposure to TSDF emissions), and noncancer health effects (from acute and chronic exposures to noncarcinogenic chemical emissions from TSDF). Annual cancer incidence and maximum lifetime risk are used as an index to quantify health impacts for the three control cases: (1) uncontrolled air emissions, (2) baseline air emissions, and (3) control under two example strategies.

Detailed discussion on the development of the health effects data presented here are found in Appendixes E and J. In general, the methodology consists of four major components: estimation of the annual average concentration patterns of TSDF organic air emissions in the region surrounding each facility, estimation of the population associated with each computed concentration, estimation of exposures computed by summing the products of the concentrations and associated populations, and, finally, estimation of annual incidence and maximum lifetime risk, which are obtained from exposure and TSDF emission potency data.

6.2.1 Annual Cancer Incidence

For the estimates of TSDF incidence, the Human Exposure Model (HEM), which uses a basic EPA dispersion algorithm, was used to generate organic emission concentration patterns. The TSDF Industry Profile (see Appendix D.2.1) was accessed to identify facility locations for population pattern estimation within the HEM using 1980 census population distributions. The HEM was run for each TSDF using a fixed unit risk factor and a facility organic emission rate; as such, the HEM site-specific incidence results can be adjusted by the annual facility emissions generated from the SAM and the appropriate TSDF unit risk factor to give facility-specific estimates for the control strategy under consideration. The incidence results therefore reflect the level of emissions resulting from a particular emission scenario or control strategy.

As shown in Table 6-3, incidence estimates indicate that an uncontrolled TSDF industry would lead to 130 cancer incidents per year nationwide; the baseline TSDF industry case would lead to 135 incidents. Example control strategy I reduces the estimated number of cancer incidences some 84 percent from 135 in the baseline case to 21 per year. Example control strategy II reduces the estimated number of cancer incidences about 89 percent from 135 incidences in the baseline to about 15 cancer incidences per year nationwide.

TABLE 6-3. NATIONWIDE CANCER INCIDENCE FROM TSDF EMISSIONS BY SOURCE CATEGORY[a,b]
(Number of Cancer Incidences/Year)

| Source category | Cancer incidence due to . . . | | Cancer incidence after . . . | |
| | Uncontrolled emissions | Baseline emissions[c] | Example control strategies | |
			I[d]	II[e]
Drum storage	0.016	0.016	0.016	0.001
Dumpster storage	6.8	6.8	0.12	0.12
Storage tanks	72.2	72.4	0.28	0.43
Quiescent surface impoundments	8.6	8.7	0.90	2.2
Quiescent treatment tanks	3.3	3.3	1.3	1.0
Aerated tanks and surface impoundments	30.3	30.4	1.6	7.5
Wastepiles	0.021	0.003	0.003	0
Landfills	1.9	0.12	0.063	0.0003
Waste fixation	0.13	9.8	13.0	0.53
Incineration[f]	0.032	0.043	0.043	0.043
Land treatment	0.56	0	0	0
Other treatment[g]	0	0	0	0.11
Spills	0.041	0.040	0.041	0.048
Loading	0.62	0.62	0.44	0.35
Equipment leaks	5.8	2.8	3.0	3.0
TOTAL	130	135	21	15

TSDF = Treatment, storage, and disposal facility.

[a]This table shows nationwide cancer incidence by emission source. Each of the four categories of incidence listed above is described in detail in Chapter 5.0. Development of incidence estimates is presented in Appendix E. This table provides only example control strategy data. It is shown only for the purpose of demonstrating the estimation of impacts of control strategies.

[b]Estimated values for each source category should not be used or viewed independently because some control technologies may suppress emissions or reduce emissions (e.g., organic removal processes) that will impact sources downstream.

(continued)

TABLE 6-3 (continued)

cWith TSDF proposed air standards (for process vents and equipment leaks) and land disposal restrictions in place.

dExample control strategy I applies to wastes containing greater than 500 ppm of organics. It entails covers and controls for tanks and impoundments, submerged loading of drums, and covers for dumpsters. For covered storage and quiescent treatment tanks, venting to a control device is required if the vapor pressure of the waste in the tank exceeds 1.5 psia.

eExample control strategy II applies to wastes containing greater than 500 ppm of organics. It entails introducing organics removal processes before treatment tanks, storage or treatment impoundments, and waste fixation processes; covers and controls for storage tanks as in example strategy I; enclosure and control of drum storage areas; submerged loading of drums; and covers for dumpsters.

fUncontrolled incinerator emissions include emissions from wastes that are routinely incinerated with stack exhaust gas emission controls. These sources are currently regulated under 40 CFR 264 Subpart 0. The uncontrolled emission scenario does not include wastes that are or would be incinerated as a result of implementing the RCRA land disposal restrictions. The baseline and two example strategies do, however, account for the incinerator emission resulting from the land disposal restrictions. The emission scenarios are explained in Chapter 5.0.

9Other treatment includes processes such as stream stripping that are typically used to remove organics from wastes. For the uncontrolled emission case, these emissions are built into the tank treatment category because of similarities in emission characteristics.

6.2.2 Maximum Lifetime Risk

Maximum lifetime risk (MLR) represents "individual" risk as opposed to the "aggregate" risk in the total nationwide cancer incidence and is intended to reflect the Nation's most exposed individual's chance of getting cancer if exposed continuously for 70 years to the highest annual average ambient concentration around a TSDF. As such, MLR reflects the highest risk that any person would have from exposure to TSDF emissions. MLR is calculated as a function of ambient organic concentration and the composite unit risk factor for TSDF organic emissions. For TSDF MLR estimates, the Industrial Source Complex Long-Term Model (ISCLT), a state-of-the-art air quality dispersion model, was used to generate the maximum annual average ambient organic concentration estimates (see Appendix J for a description of the model). In order to provide a more comprehensive analysis of maximum ambient concentrations, two TSDF were selected for detailed, rigorous analysis in making MLR estimtes. The two facilities were selected on the basis of their estimated emissions and the TSDF management processes utilized at the facilities. The design and operating parameters and wastes managed at these two facilities were used in conjunction with the local meteorological conditions (standard climatological frequency of occurrence summaries) to estimate dispersion of emissions from each source at each facility on an annual basis. Multiplying the maximum annual average ambient concentration by the composite unit risk factor yields the maximum risk, given that someone is predicted to reside at that location. The unit risks from the various individual dispersed carcinogens are represented by a composite unit risk factor for TSDF organic emissions. Pertinent information on the selected TSDF and unit risks is presented in Appendix J and Appendix E, respectively.

The results of the MLR calculations, shown in Table 6-4, indicate that the probability of contracting cancer is 1×10^{-2} for the baseline TSDF industry. For example control strategies I and II, these risks are 4×10^{-4} and 5×10^{-4}, respectively. For both example strategies, surface impoundments are the major sources contributing to the maximum ambient air concentrations associated with the MLR values.

TABLE 6-4. MAXIMUM LIFETIME RISKS FROM
TSDF EMISSIONS[a]

Control scenario	Maximum concentration, $\mu g/m^3$	Maximum risk[b]
Uncontrolled	1,700	1×10^{-2}
Baseline	1,700	1×10^{-2}
Strategy I[c]	50	4×10^{-4}
Strategy II[c]	60	5×10^{-4}

[a]This table shows the cancer risk of the individual in the United States most exposed to TSDF emissions over a 70-year period. Risk is presented for four control scenarios, which are described in detail in Chapter 5.0. Development of risk data is presented in Appendixes E and J.

[b]Based on a composite risk factor of 8.6×10^{-6} $(\mu g/m^3)^{-1}$.

[c]Based on 500 ppm volatile organic cutoff and an additional cutoff of 1.5 psia for storage and quiescent treatment tanks (to determine level of control required).

6.2.3 Noncancer Health Effects Assessment--Acute and Chronic Exposures

A screening analysis of the potential adverse noncancer health effects associated with acute and chronic exposure to individual waste constituents emitted from the two selected TSDF was based on a comparison of relevant health data to the highest short-term (i.e., 15-min, 1-h, 3-h, and 24-h) or long-term (i.e., annual) modeled ambient concentrations for chemicals at each facility (see Appendix E). Modeled concentrations were estimated from the Industrial Source Complex-Short Term (ISCST) Model. Detailed information on this model and on modeled ambient concentrations of constituents at each facility is provided in Appendix J.

Results of this analysis indicate that adverse noncancer health effects are unlikely to be associated with acute or chronic exposure to the given ambient concentrations of individual chemicals at these two TSDF. Modeled short-term and long-term ambient concentrations were in most cases at least three orders of magnitude below health effects levels of concern. It should be noted that the health data base for many chemicals was limited, particularly for short-term exposures. The conclusions reached in this analysis should be considered in the context of the limitations of the health data, the uncertainties associated with the characterization of wastes at the two facilities, and the assumptions used in estimating emissions, ambient concentrations, and the potential for human exposure.

6.3 OTHER ENVIRONMENTAL IMPACTS

(Data to support this section are currently under development.)

7.0 NATIONAL CONTROL COSTS

The purpose of this chapter is to present the general methodology used to estimate nationwide costs of adopting each of the two example control strategies described in Chapter 5.0 as the basis for regulation of air emissions from hazardous waste treatment, storage, and disposal facilities (TSDF). Estimated nationwide total capital investment (TCI; i.e., equipment purchase and direct and indirect installation costs) and total annual costs (TAC; i.e., costs of operating control technologies minus any energy or materials credits) are provided in a subsequent section of this chapter. In addition, the cost per unit of waste throughput for the control technologies identified in Chapter 5.0 as part of the example control strategies is discussed and listed, and a general explanation of the methodology used to derive those unit costs is presented in this chapter. Supporting data are provided in Appendixes H and I to this document, and other references to cost information are listed in those appendixes.

Development of costs requires the presumption of a baseline level of emissions and emission control from which the control costs can be calculated. The baseline used for this effort is described in Chapter 5.0, Section 5.1, of this document. Costs to implement the example control strategies are provided to permit a comparison of the resources that would be expended to reduce air emissions from TSDF using different combinations of controls and sources.

7.1 CONTROL COSTS DEVELOPMENT

Estimation of the nationwide costs of adopting a control strategy begins with estimation of the control costs for individual waste management units within a TSDF. Ideally, information about the design and operating characteristics (such as surface area and retention time for impoundments) of each waste management unit would be available to permit accurate

estimates of control costs for that unit. Information at that level of detail is not available for each unit at each facility; generally, only waste throughput is known. For this reason, model units were developed. Rationale for the development of model units is given in Chapter 3.0, Section 3.2.1 (as relates to emission estimation) and Section C.2. Control cost estimates were developed for each of the model units as well as organic removal processes and hazardous waste incineration (results are shown in Section C.2.3). The methodology for developing control costs for the model units and the other processes is described partially in Section 7.1.1 and in detail in Appendixes H and I.

To obtain nationwide costs from model unit costs requires a method of assigning a model unit cost to each waste management unit in each facility and then computing the sum. Given that only TSDF waste management unit throughput is known, the assignment of one of the defined model units to represent each TSDF waste management unit is not possible. Therefore, a weighted average model unit control cost--in essence, "national average model unit" control cost--was derived for each control applied to each TSDF waste management unit. These control costs, divided by the model unit throughput, provide cost factors that are used to generate control cost estimates for each TSDF facility. The discussions of weighted average model unit control costs and control costs as a function of throughput are given in Sections 7.1.2.2 and 7.1.2.1, respectively.

7.1.1 Methodology for Model Units, Organic Removal, and Waste Incineration Control Costs

To estimate the nationwide cost impacts of implementing the two example control strategies presented in Chapter 5.0, the estimated total capital investment and total annual costs were developed for each of the various control technologies applied in the control strategies. (A general discussion of these control technologies is contained in Chapter 4.0.) The control strategies describe the control technology for each source category in general terms, such as cover and vent to control device. The specific control technologies assumed to be applied to each source category for each example strategy are defined in Chapter 5.0, Section 5.2.

A standardized cost estimating approach was developed for add-on and suppression-type control devices and organic removal processes based on an

EPA cost manual[1] and a series of articles by Vatavuk and Neveril.[2-7] These sources identified the total capital investment, annual operating costs (costs of operating control technologies minus capital recovery and energy credits), and the total annual costs (i.e., annualized costs) as the key elements of a cost estimate. Costs of incineration control technologies were developed using information provided by the Office of Solid Waste (OSW).[8] These approaches are discussed in greater detail in Appendixes H and I.

For each control technology applied in a control strategy, a detailed cost estimate was developed. The detailed cost estimate consisted of three standard cost tables. The first of the three cost tables lists the major equipment items associated with the control technology. The second table lists any auxiliary equipment required, instrumentation, sales tax and freight, plus direct and indirect installation charges. These first two tables are used to calculate total capital investment. The third table lists the direct operating costs, indirect operating costs, and energy credits used to calculate total annual costs. Examples of these three tables are presented in Appendix H.

The purchase cost, material of construction, and size of each major equipment item were obtained from vendor data, engineering handbooks, the literature, and currently operating commercial facilities. (Such sources are referenced in Appendixes H and I.) The sum of the costs for the major equipment items is equal to the base equipment cost (BEC).

Using the base equipment cost, the purchased equipment cost (PEC) for the control technology is computed. Direct and indirect installation charges for each control technology are factored directly from the purchased equipment cost. For this analysis, the direct and indirect installation factors are based on information obtained from vendors, other cost estimates, data summarized in References 2 through 7, and engineering judgment based on typical TSDF wastes and operating practices. The costs for site preparation and buildings were based on vendor information and construction cost reference sources.[9] The sum of the purchased equipment cost, direct installation charges, and indirect installation charges are equal to the total capital investment (TCI).

The sum of direct and indirect operating expenses less capital recovery and energy credits is equal to the annual operating costs. The total annual cost is equal to the direct plus indirect operating costs less any energy credits.

To illustrate this cost approach for add-on control devices and for organic removal processes, Appendix H gives a detailed cost analysis for application of a fixed roof to an open tank vented to a fixed-bed carbon adsorption system, and Appendix I shows the analysis for steam stripping of a dilute aqueous waste. Similar analyses were performed for the other control technologies used in the example strategy definitions in Chapter 5.0 and are contained in the document that provides the rationale of the design, costing, and material and energy balances for TSDF control options.[10] In addition, this document provides flow diagrams for organic removal processes, sample calculations, and other details of how each control was costed.

The costs for waste incineration were not developed from basics, but made use of a detailed study of hazardous waste incineration performed for the OSW.[11] In the OSW study, incineration costs for a variety of wastes were estimated. Several of the OSW incineration estimates for wastes with compositions similar to model wastes described in Appendix C, Section C.2.2, were selected as the basis for the TSDF incineration costs. This cost-estimating effort is described in more detail in Appendix I.

7.1.2 Derivation of Unit Costs to Estimate Nationwide Costs of Example Control Strategies

The estimation of nationwide costs of the example control strategies makes use of a TSDF Industry Profile data base (assembled to aid in this effort and described in Appendix D) and the emission control costs for individual source category/emission control combinations whose development is discussed in Appendixes H and I. The Industry Profile gives the waste throughput data used to assign throughputs to each TSDF waste management unit. To facilitate the use of these two information sources, the total capital investment and annual operating cost for each of the model unit cost estimates were divided by the throughput of the model waste management unit (emission source) to obtain a cost (both total capital investment and

annual operating cost) per unit of waste throughput. The following paragraphs discuss the development of the unit cost factors.

7.1.2.1 <u>Costs as a Function of Throughput (Unit Cost Factors)</u>. As part of the effort to characterize the variety of TSDF operating practices, model TSDF waste management units were defined. The main purposes of the model units are to evaluate uncontrolled emissions from waste management processes, assess the reduction in air emissions when emission controls are applied, and estimate the costs of applying controls. Model units were defined for TSDF storage, transfer and handling, treatment, and disposal operations. The model units cover a range of waste management unit sizes (e.g., throughput, surface area, and tank volumes) and other characteristics that may impact air emissions. The entire set of model units is presented in Appendix C of this document. The approach to developing control costs discussed in Section 7.1.1 was applied to each of the model units listed in Appendix C for each of the individual unit emission controls.

The next step toward generating the control costs on a nationwide basis was to convert the costs of controls for the model units, organic removal processes, and incineration operations to a cost per unit of waste throughput; i.e., the costs of controlling emissions from each model unit or other process were divided by the annual waste throughput of the model waste management unit to which the control was applied. These factors (referred to as unit cost factors), when multiplied by the waste throughput for a particular waste management unit, yield an estimate of the cost of air emission controls for that unit.

7.1.2.2 <u>Development of Weighted Cost Factors</u>. Data contained in the TSDF Industry Profile (described in Appendix D) are used to estimate annual waste throughput for each type of waste management unit at each TSDF. The Industry Profile, however, does not yield the exact size of each management unit, e.g., 758 m^3 of tank storage could be ten 75.8-m^3 tanks or one 758-m^3 tank. Because there are economies of scale associated with emission control costs, the total control costs might be substantially different for these two examples. To compensate for the lack of facility-specific unit size information, weighted unit cost factors were developed that account

for the national size distribution of TSDF waste management units.
Statistics on the national distribution of waste management unit sizes were
used to weight the emission control costs for each model unit size defined
in Appendix C.[10] This approach yields an approximation of the effects of
economies of scale for the nationwide cost estimates.

The cost weighting procedure was not used for organic removal and
hazardous waste incineration processes. These processes would typically
not be used to handle waste streams with a low throughput. The throughputs
used for estimating the costs of these processes were selected to be within
the range of existing on-site operations for air and steam strippers and
commercial-scale operations for batch distillation, thin-film evaporation,
and incineration. Consequently, single point unit cost estimates were used
for these processes at relatively large unit sizes where changes in
throughput would not yield major changes in economies of scale.

Table 7-1 lists the unit cost factors used to estimate nationwide
total capital investment and annual operating costs for each of the emis-
sion controls specified in the example control strategies.

7.2 SUMMARY OF NATIONWIDE CONTROL COSTS FOR CONTROL STRATEGIES

This section presents tabular summaries of the estimated nationwide
total capital investment and total annual costs (annualized capital cost
plus annual operating costs) for the two example control strategies
described in Chapter 5.0. Separate cost estimates are given for each TSDF
source category.

The nationwide cost estimates were obtained by multiplying the quan-
tity of wastes managed in each TSDF waste management unit (obtained from
the TSDF Industry Profile) by the unit cost factors listed in Table 7-1.
The estimated costs for each TSDF were summed to produce national totals.
Table 7-2 lists the estimated nationwide total capital investment and the
estimated nationwide total annual cost, respectively, for each of the exam-
ple control strategies.

For the example strategies, the estimated total capital investment for
control strategy I is $1.084 billion and for control strategy II is $7.19
billion. The estimated total annual costs (i.e., annualized costs) are
$0.433 billion for strategy I and $2.17 billion for strategy II. It can be
observed in Table 7-2 that the emission control costs for tank storage are

TABLE 7-1. ESTIMATED TOTAL CAPITAL INVESTMENT AND TOTAL ANNUAL COST PER
UNIT OF WASTE THROUGHPUT BY SOURCE CATEGORY FOR TWO EXAMPLE
CONTROL STRATEGIES[a]

Source category	Total capital investment, $/Mg throughput[c] Example control strategy[b]		Total annual cost, $/Mg throughput[c] Example control strategy[b]	
	I	II	I	II
Drum storage	0	49-91	0	21-38
Dumpster storage	6.3-26	6.3-26	2.1-9.9	2.1-9.9
Storage tank	9.7-28	9.7-28	4.9-15.0	4.9-15.0
Quiescent surface impoundments	1.9-2.6	0	0.87-4.8	0
Quiescent treatment tanks	0.22-1.2	0	0.14-0.58	0
Aerated/agitated tanks and impoundments	0.41-2.9	0	0.26-1.7	0
Wastepiles	0g	0g	0g	0g
Landfills	0g	0g	0g	0g
Waste fixation	0	0	5.1	0
Incineration[d]	0	290-480	0	110-150
Land treatment	0g	0g	0g	0g
Other treatment[e]	0	3.5-66	0	(23.0)[h]-21
Spills	0	0	0	0
Loading	0.49-0.89	0.49-0.89[i]	0.09-0.17[i]	0.09-0.17[i]
Equipment leaks[f]	0.02-48.0	0.02-48.0	<0.01-1.50	<0.01-10.0

[a]Total capital investment includes all costs to purchase equipment, direct installation charges, and indirect installation charges. Total annual cost is the sum of the annual operating cost and the annualized capital costs. All costs are in January 1986 dollars.

[b]The two example control strategies are described in Chapter 5.0. The first strategy depends predominantly on the use of add-on controls, and the second strategy offers an option of add-on controls or organic removal.

[c]The unit costs were obtained from information presented in Appendixes H and I. Where a cost range is given, the range represents cost variations due to differences in waste composition. Model waste compositions for which costs were derived are presented in Appendix C.

[d]Incineration represents alternatives to organic removal from the waste organic sludges and organic-containing solids.

[e]Other treatment represents organic removal processes such as steam distillation. Vents from these processes would be regulated under the treatment, storage, and disposal facility (TSDF) air standards for fugitive emissions and process vents proposed February 7, 1987.

[f]This source category will be regulated by the proposed TSDF air standards for equipment leaks and process vent controls.

[g]As noted in Chapter 5.0, these source categories are regulated by the Resource Conservation and Recovery Act land disposal restrictions.

[h]Parenthetical numbers denote negative values, which means there is a net credit for applying the control to the source category.

[i]Example control strategies address only controlling drum loading.

TABLE 7-2. ESTIMATED NATIONWIDE TOTAL CAPITAL INVESTMENT AND TOTAL ANNUAL COST
FOR TWO EXAMPLE CONTROL STRATEGIES[a]

Source category	Total capital investment, 10^6 Example control strategy[b]		Total annual cost, 10^6 Example control strategy[b]	
	I	II	I	II
Drum storage	0	1,640	0	678
Dumpster storage	13.2	13.2	5.103	5.103
Storage tank	162	235	49.5	89.6
Quiescent surface impoundments[c]	839	0	349	0
Quiescent treatment tanks[c]	6.89	0	1.44	0
Aerated/agitated tanks and impoundments[c]	46.9	0	24.6	0
Wastepiles	0[g]	0[g]	0[g]	0[g]
Landfills	0[g]	0[g]	0[g]	0[g]
Waste fixation[c]	0	0	0	0
Incineration[d]	0	370	0	143
Land treatment	0[g]	0[g]	0[g]	0[g]
Other treatment[e]	0	4,920	0	1,250
Spills	0	0	0	0
Loading	16.01[h]	16.01[h]	3[h]	3[h]
Equipment leaks[f]	0	0	0	0
Total	1,084	7,190	433	2,170

[a]Total capital investment includes all costs to purchase equipment, direct installation changes, and indirect installation charges. Total annual cost is the sum of the annual operating cost and the annualized capital costs. All costs are in January 1986 dollars.

[b]Example control strategy I is based predominantly on the use of add-on emission controls. Example control strategy II also requires the use of add-on emission controls unless the waste stream is pretreated by organic removal. The example control strategies are described in Chapter 5.0.

[c]In example control strategy II, the costs for these source categories are included in the organic removal costs.

[d]Incineration represents alternatives to organic removal from the waste organic sludges and organic-containing solids.

[e]Other treatment represents organic removal processes such as steam distillation. Vents from these processes would be regulated under the treatment, storage, and disposal (TSDF) air standards for fugitive emissions and process vents proposed February 7, 1987.

[f]This source category will be regulated by the proposed TSDF air standards for equipment leaks and process vent controls.

[g]As noted in Chapter 5.0, these source categories are regulated by the Resource Conservation and Recovery Act land disposal restrictions.

[h]Example control strategies address only controlling drum loading.

higher for control strategy II than for control strategy I, even though the specified controls are the same for both strategies. The difference is attributable to the fact that, when organic removal process are used in a facility that has no drum or tank storage present before control, it is assumed that tank storage capacity must be added to the facility to serve the organic removal process equipment.

The nationwide cost information presented in this chapter provides two means of comparing control strategy capital and annual costs. Other means of comparing strategies are discussed in Chapter 5.0. Section 5.5 describes a methodology for ranking control strategies according to the relative health and environmental benefits achieved by the strategies.

7.3 COST EFFECTIVENESS OF CONTROL STRATEGIES

Table 7-3 shows the cost effectiveness of the two example control strategies. The cost effectiveness of a control strategy is defined as the total annual cost of applying controls to all emission sources covered by the strategy divided by the total emission reduction that would be achieved. Total annual cost is the annual operating cost plus the annual cost of capital required to purchase and install the controls. As shown, the cost effectiveness of example strategy I and example strategy II is $294/Mg and $1,460/Mg of organic emission reduction, respectively.

Only a single aggregate cost effectiveness is presented for each TSDF control strategy. The cost effectiveness of controlling specific emission source categories covered by a strategy (e.g., the cost effectiveness of controlling storage tanks) is not presented. This is because emissions from TSDF sources are interrelated in many strategies and, consequently, it is potentially misleading to estimate the cost effectiveness on an emission source category basis.

For example, covering only the first of several TSDF waste management units (emission sources) in series will reduce organic emissions from the unit that is covered but may increase the emissions from the uncovered units downstream, resulting in no change in total facility emissions. The cost effectiveness of controlling the first unit may look attractive in isolation, but, as a practical concern, reduction in total facility emissions would not be achieved unless units downstream were controlled as well.

TABLE 7-3. NATIONWIDE TSDF COST EFFECTIVENESS OF TWO
EXAMPLE CONTROL STRATEGIES[a]

Example control strategy[b]	Cost effectiveness $/Mg emission reduction
I	294
II	1,460

[a]This table presents total annual costs of control divided by organic emission reductions, i.e., cost-effectiveness.

[b]Example control strategy I is based predominantly on the use of add-on emission controls. Example control strategy II also requires the use of add-on emission controls unless the waste stream is pretreated by organic removal. The example control strategies are described in Chapter 5.0.

7.4 REFERENCES

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