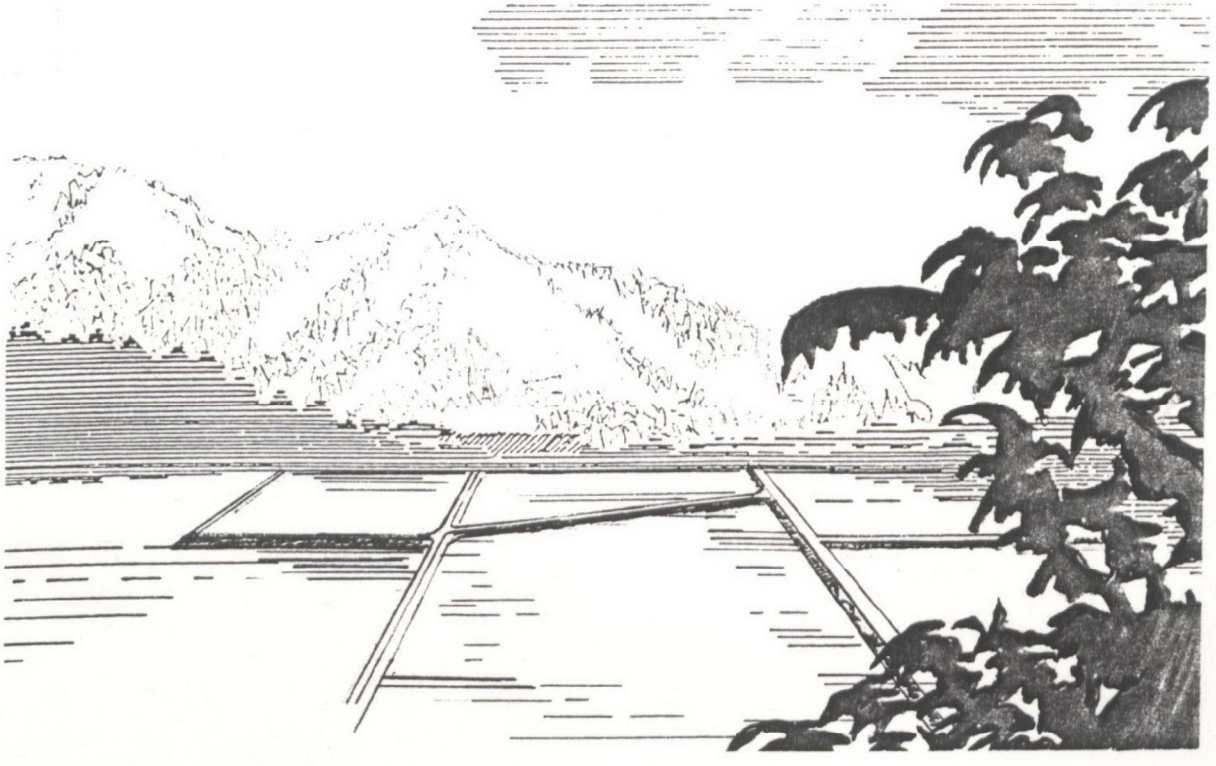
AIR TOXIC EMISSIONS FROM SELECTED NON-TRADITIONAL SOURCES IN THE PUGET SOUND REGION



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DETERMINATION OF AIR TOXIC EMISSIONS FROM NON-TRADITIONAL SOURCES IN THE PUGET SOUND REGION

Prepared for

The U.S. Environmental Protection Agency
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and the

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DETERMINATION OF AIR TOXIC EMISSIONS FROM NON-TRADITIONAL SOURCES IN THE PUGET SOUND REGION

SUMMARY

In the past few years there has been increasing interest in identifying the potential public health problems resulting from the emissions of toxic air contaminants for which ambient air quality standards do not currently exist. A key element in assessing the effects of these so-called toxics is determining the quantity of emissions of contaminants of concern. As with criteria pollutants there are both point and area sources of such contaminants requiring a review of a broad variety of potential sources. The Puget Sound Air Pollution Control Agency in 1983 began an air toxic inventory program addressing traditional point sources to quantify toxic emitters. As this inventory was nearing completion, it was becoming clear through research by EPA and others that a number of non-traditional air pollution sources may in fact be important sources of toxic air pollutants. To help identify and understand the scope of such emissions of air toxics, Puget Sound Air Pollution Control Agency requested assistance from EPA Region 10 in developing emission estimates for several selected non-traditional sources. The resulting plan established five source categories for investigation: Publicly Owned Treatment Works (POTW); Industrial Wastewater Treatment Plants; Superfund Clean-up Sites; Municipal Landfills; and Hazardous Waste Treatment Storage and Disposal Facilities (TSDFs). To ensure a broad review of non-traditional sources, emissions were to be estimated for facilities from each category. Because details of processes and wastes handled are critical to potential emissions, site visits were planned to key representative facilities within each of the source groups. Where appropriate and beneficial, considering available resources, field samples or measurements were to be taken to allow improved emission estimation. The facilities eventually visited within each source category are listed below:

Publicly Owned Treatment Works

METRO West Point Treatment Plant
METRO Renton Treatment Plant
Everett Wastewater Treatment Plant
Chambers Creek Wastewater Treatment Plant

Industrial Wastewater Treatment

Weyerhaeuser - Everett
Scott Paper - Everett
Wyckoff

Superfund Clean-up Site

Tacoma Tar Pits

Municipal/Public Landfills

Hidden Valley
Cedar Hills

Hazardous Waste Treatment, Storage and Disposal Facilities

Chemical Processors, Inc. - Georgetown
Lilyblad Petroleum

The information garnered as a result of these visits was used to augment and refine emission estimates prepared for similar facilities within each category.

In evaluating emissions, no selected or limited list of toxic materials was used; however, almost all available analyses of waste waters were prepared to evaluate the presence of EPA's priority pollutant list. Although this list includes many materials of low volatility, it was found that several of these are being emitted as air toxics. However, their low volatility does aid in limiting emissions in cases where direct evaporation is a dominant emission

mode such as chemical process losses and conditions of surficial evaporation where there is little restriction due to diffusion. Table S-1 lists the largest sources of toxic air contaminants identified as a result of the estimates made here. As may be seen, industrial and publicly-owned wastewater treatment works can show substantial emissions though this is closely tied to the presence of volatile contaminants combined with aerated treatment. In addition, it is important to note that the estimates for wastewater treatment are conservative since they give no credit to other removal modes such as removal by biological action or adsorption on solids. In addition, VOCs in POTW effluents may still be emitted from receiving waters. Landfills also are significant sources mainly due to bio-gas flux which carries with it trace quantities of toxic components. Actual fluxes have not been measured at Puget Sound landfills, however, and these estimates are based on landfill gas production models which are admittedly imprecise estimators of overall amounts. Another important caveat regarding the accuracy of landfill estimates results from uncertainties regarding the effectiveness of flaring. No data exist of flare gas flow rates and destruction efficiencies for most landfills in the area. In addition, flares tend to self-extinguish. Records for relighting which helped assess outage periods were available for three landfills only.

Analysis of hazardous waste handlers and Superfund sites showed relatively small emission potential. Hazardous waste treatment, storage, and disposal sites reviewed here simply did not handle large quantities of toxic material making overall emissions relatively small except for the listed solvent recyclers. In addition, much of the very large tonnage associated with listed organic wastes (ignitables or waste solvents) results from large percentages of water in the combined waste. Superfund sites analyzed were, for the most part, those considered most critical with the largest potential for emissions. In each case, however, volatiles with the greatest emissions potential were found at low concentration in soils scheduled for removal (most volatiles probably left before or shortly after the waste got into the soil). Material remaining at high concentration were largely heavier volatiles (toluene, xylene and derivatives), polycyclic aromatic hydrocarbons, oily wastes, and metals.

TABLE S-1

SUMMARY OF COMBINED TOXICS EMISSIONS[a]
FOR THE LARGEST SOURCES EVALUATED
WITHIN DESIGNATED SOURCE CATEGORIES

Facility	Source	Emission Estimate (Ton/Year)
Weyerhaeuser Kraft	Aeration Lagoon	35 - 492[b]
Scott Paper Kraft	Secondary wastewater treatment	18.2
Simpson Tacoma Kraft	Wastewater treatment	2.3
Kent Highlands Landfill	Landfill gas/flares	11.3
Hidden Valley Landfill	Landfill gas/flares	12.3
Cedar Hills Landfill	Landfill gas/flares	10.8
Olalla Landfill	Landfill gas/flares	3.1
Lilyblad Petroleum	Solvent Recovery	1.4
Northwest Enviro Services	Oily/Solvent Water treatment	2.4
Chemical Processors	All	1.1
METRO-Renton POTW	All	8.6
Everett POTW	All	1.2
Chambers Creek POTW	All	0.8
Puyallup POTW	All	0.7
Brownsville POTW	All	0.5
METRO-West Point POTW	Primary Sedimentation	0.4

[a] The above estimates include the following compounds: Acetone, Benzene, Carbon Tetrachloride, Chloroethane, Chloroform, Dichloroethane, Dichloroethylene, Methylene Chloride, Naphthalene, Phenol, Tetrachloroethylene, Toluene, 1,1,1,-Trichloroethane, Trichloroethylene, among others. For a compound-by-compound breakdown see pages 35-52 and A1 through A24.

[b] The high value of this range is based upon a single sample of wastewater taken during what is believed to have been a batch release of chemicals. Weyerhaeuser emission estimates are discussed on page 41.

Clearly industrial wastewater treatment presents a potentially significant source group of toxic emissions. It also is a group for which only limited information is available, usually a one-time effluent analysis to determine compliance with discharge permit regulations. These sources will require detailed investigations to prepare improved estimates of alternative removal mechanisms and validate surface impoundment and treatment tank emission rates.

In general, refinement of the values in Table S-1 will require further field testing to verify critical concentrations and quantities. For example, it is suspected the large emissions attributed to Weyerhaeuser may be due to a batch release of bleach chemicals rather than an average value. This on-going analysis and inventory development should be directed primarily at refining industrial wastewater treatment and landfill emission values.

DETERMINATION OF AIR TOXIC EMISSIONS FROM NON-TRADITIONAL SOURCES IN THE PUGET SOUND REGION

INTRODUCTION

In recent years, greater interest has been expressed by regulatory agencies in identifying and controlling sources of toxic air contaminates. This interest has been due chiefly to two reasons: First, implementation of programs to control criteria pollutants have largely been put in place; and second, it is clear that many volatile organic compounds and particulates have toxic effects beyond those contemplated when the original criteria pollutant standards were established. Many regulatory agencies have begun to identify toxic air contaminant point sources through inventory efforts aimed at major sources of volatile organic compounds and heavy metals. For the most part, these sources were already on existing inventory lists due to their emission of other criteria pollutants. These efforts have been aimed at better identifying the significance of the pollutants through identification of the individual toxic species that may be emitted.

During 1983 and 1984, the Puget Sound Air Pollution Control Agency (PSAPCA) began such an inventory of point sources within its area of jurisdiction in order to identify toxic air contaminant emissions. As a result of investigation associated with this inventory effort and with the findings of other investigations in other areas, it became clear that many of the toxic air contaminant emissions may result from so called non-traditional sources. Of particular interest because of their potential emissions are such sources as: wastewater treatment plants for public, private and industrial uses; landfills; hazardous waste treatment, storage, and disposal facilities; and abandoned hazardous waste disposal sites, including Superfund sites. In order to critically assess the emissions of the toxic air contaminants from such operations, it is necessary to gather basic information about source processes

such as the types of toxic materials that are handled, the amounts of material which are handled, and the method of transfers of toxic material from one process to another. A particularly important factor is the concentration of the hazardous or toxic material in the waste that is being handled.

Clearly the evaluation of toxic emissions for all potential toxic materials from a wide variety of sources is a difficult and time consuming task. In order to reduce the amount of work to be performed under this contract, it was decided that Engineering - Science would prepare emission estimates for some 50 non-traditional sources located in the PSAPCA area of jurisdiction. The emission estimates prepared for these sources, would be supported by data collected during site visits to a selected number of the potential sources. Both the original 50 sources and those to be observed during site visits were selected to represent a larger number of sources located in the area. Thus, both emissions estimates and emission estimation procedures would have broad application to other sources of toxic air contaminants. It was intended that site visitation procedures, sampling and analytical methods for materials containing potential toxic air contaminants, and emissions estimations methods would serve as a guide to PSAPCA during the completion of its air toxic inventory.

Emission estimation procedures for non-traditional sources of air pollution are not well developed. Standard emission factors do not exist. Because of the wide variety of potential toxic emissions and levels of concentration in materials handled, simplified emission estimation methods such as exist for criteria pollutants have not been prepared for non-traditional sources. In addition, traditional methods for measuring emissions from point sources such as stack testing and material balance are more difficult to apply to non-traditional sources where emissions may occur over large areas (e.g. lagoons).

Methods for measuring emissions of material from a large area are generally expensive requiring large commitments of time and equipment in the field. As a result, calculations of emissions for large areas such as landfills and surface impoundments are based primarily on the mathematical modeling of the

diffusion of volatile material through liquids and solids and material balance data. Unfortunately, use of emission estimation models is not a simple alternative. They often require detailed information with regard to the nature of the potential air contaminants and the waste in which it is mixed. Of necessity, they tend to simplify the physical conditions under which emissions occur, thereby making them less representative of the actual emission problem. However, they do allow estimation of the emissions for a large number of sources for which field studies would be impractically expensive.

IDENTIFICATION OF POTENTIAL SOURCES

In order to limit the amount of contractor effort involved in identifying sources of potential emission, the Puget Sound Air Pollution Control Agency (PSAPCA) prepared a draft report entitled "Identification of Potential Non-Traditional Sources of Toxic Air Pollutants in the Puget Sound Region" (Kircher, 1985). This report relied upon existing information for hazardous waste handling, landfills, publicly owned treatment works, and Superfund sites for preparing a list of potential toxic air contaminant sources. Utilizing existing lists resulted in relatively limited information with regard to any individual source. However, it did allow the rapid tabulation of general information about a wide variety of sources with potential TAC emissions. The PSAPCA report addresses potential TAC emissions from five source areas: 1) publicly owned treatment works (sewage treatment); 2) active and abandoned landfills; 3) potential and listed superfund sites; 4) industrial wastewater treatment; and 5) hazardous waste treatment, storage, and disposal. For each of these potential source areas, evaluation of existing facility data was followed up by detailed telephone conversations with source owners and operators. This information was used to select the limited number of sources to be included in this study and to be the subjects of site visitation. A discussion of the procedures for selecting sources in each category is given below.

Publicly Owned Treatment Works (Sewage Treatment Plants)

A general listing of publicly owned treatment works was prepared based upon telephone conversations with METRO, the City of Seattle, the Washington State Department of Ecology, and investigation of various environmental impact studies prepared for comprehensive land use and other planning needs. Data on the capacities and types of treatments at METRO facilities was provided directly to PSAPCA as were reports regarding toxicant pre-treatment and treatment. Information regarding other facilities was drawn largely from the National Pollution Discharge Elimination System (NPDES) permit data which basically identify the locations of treatment plants. Some detailed information was available on a very limited number of facilities through environmental impact statements or other studies which have been prepared to identify

treatment difficulties, potential client sources, and general benefits of treatments to surface waterways. Through a special request to the Washington Department of Ecology (WDOE), PSAPCA identified all treatment facilities, their capacities, and the types of treatments used. This resulted in a listing of some 55 publicly owned treatment works with capacities varying from 29,000 gallons to 125 million gallons per day. Treatment methods varied from sophisticated secondary treatment, using activated sludge, and anaerobic digestion, to simple primary treatment for removal of solids.

Treatment works were selected from this list of 55 facilities based on the need to investigate both potentially large sources of toxic air contaminants as well as sources that would be representative of a broad spectrum of treatment works. With the knowledge that secondary treatment, especially that conducted in aerated lagoons or aerated or agitated tanks, has the potential for significantly greater emissions than simple primary treatment, interviews were conducted with a number of treatment works operators in order to identify both large and representative facilities for further investigation. Based on these discussion, four treatment works were selected for on-site visits. Selection of other treatment works for emission estimation was prioritized based on overall capacity and potential to emit air toxics. The final list of POTWS to be evaluated is shown in Table I.

Active and Abandoned Landfills

PSAPCA investigated active and abandoned landfills through existing EPA and WDOE files and status reports on solid waste management facilities. In addition, both the WDOE and the EPA information on potential Superfund sites, many of which are abandoned landfills, was investigated. The basis for investigation and documentation of landfill activities is rarely air pollution potential. The priorities assigned by regulatory agencies tend to reflect the potential environmental problem in a general sense. Thus, the agency prioritizations can be used only as a guideline in making preliminary selections of landfills for further investigations of air emissions. The priorities can be modified based on the availability of additional information such as the types of waste that have entered the landfill, the nature of businesses of major generators whose waste entered the landfill, and any specific information

TABLE I
LISTING OF NON-TRADITIONAL SOURCES
SUBJECT TO AIR TOXIC EMISSION ESTIMATES

Publicly Owned Treatment Works

METRO, West Point*
METRO, Renton*
METRO, Alki
Chambers Creek*
Puyallup
Tacoma Northend
Tacoma Central
Edmonds
Everett*
SW Suburban (Miller Creek)
Bremerton
Lake Haven (Redondo)
Snohomish
Enumclaw
Des Moines SD
Brownsville
Lakehaven (Lakota)
METRO, Carkeek Park
METRO, Richmond Beach
SW Suburban (Salmon Crk)
Alderwood Water Dist.
Sumner
Marysville
Lake Stevens
Westside
Tacoma (Western Slopes)
Lynnwood

Industrial Wastewater Treatment

Simpson Tacoma
Scott Paper*
Wyckoff*
Weyerhaeuser*

Active and Abandoned Landfills

Cedar Hills*
Kent Highlands
Midway
Hidden Valley (Thun Field)*
Olympic View
Hansville
Ollalla

Significant Superfund Sites

Western Processing
Tacoma Tar Pits*
Queen City Farms

Hazardous Waste Treatment, Storage, and Disposal

Lillyblad Petroleum*
Chemical Processors*
Safety Kleen - Auburn
Safety Kleen - Renton
Northwest Enviro Service
Boeing Plant 2
Boeing Renton
Crosby and Overton

* Facilities visited as part of field investigations.

about volatile organic compounds, or toxic particulate matter. For generalized lists, some 200 landfills were identified in the four county area subject to PSAPCA jurisdiction. Many of these clearly have limited potential for air pollution. However other sites may be considered significant potential sources of air contaminants because of known releases of toxic gases, the existence of both putrescible and hazardous material in the same fill, large overall size or the presence of significant quantities of industrial waste. An initial screening of these sites based on readily available data was followed up with telephone interviews with site operators. The combined information from these activities resulted in the list of selected landfills identified in Table I.

Potential and Listed Superfund Sites

Puget Sound staff members collected information on uncontrolled hazardous waste sites within the State of Washington. These sites which are being investigated by the Environmental Protection Agency and the State Department of Ecology include some 450 locations across the state and about 200 in the Puget Sound Air Pollution Control Agency's jurisdiction. As part of the Superfund evaluation process preliminary assessments have been conducted on about 160 of the sites. The preliminary assessments are intended to provide some early evaluation of the environmental hazard associated with the given location. A prioritization of each site in accordance with evaluation criteria indicates the need for and urgency of action. Unfortunately, these preliminary assessment reports rarely provide sufficient data to quantify emissions though they may present the conclusion that air emissions do exist.

Based on the priorities assigned to Superfund sites as result of EPA/WDOE assessments and upon its understanding for potential air emissions from individual sites, Puget Sound staff suggested individual sites for investigation under this study. Further investigation of these PSAPCA priority sites was carried out by Engineering-Science through telephone conversations with EPA site clean-up managers. As a result of these conversations, the list in Table I was developed for site investigation as part of this study. These sites were prioritized based on indications of gas releases at the clean-up site, knowledge that volatile organic compounds were handled or disposed of at

the site, clear knowledge that toxic materials were involved and a potential for exposure to surrounding populated areas.

Industrial Wastewater Treatment

Relatively limited data are available on industrial wastewater treatment facilities within the PSAPCA jurisdiction. Only general summary information is available from the NPDES permit program. NPDES information indicating the type of treatment utilized was of some value in estimating potential air emissions, however, because of the limited value of the NPDES information, PSAPCA investigated hazardous waste data which provided significantly more information about the types of specific chemicals handled. The combined NPDES and hazardous waste information was utilized to prioritize industrial wastewater treatment facilities for site visits. Prioritization criteria for these sites included not only the potential size and toxicity of the emissions, but how well they represented other industrial activities within the Puget Sound area. Selected sites are listed in Table I.

Hazardous Waste Treatment, Storage and Disposal Facilities

Hazardous wastes are regulated through both the Washington Department of Ecology and the Environmental Protection Agency. A potentially large air emissions source group includes those facilities which treat, store and dispose of hazardous wastes as defined under the Resource Conservation and Recovery Act (RCRA). At PSAPCA request, the Department of Ecology prepared a listing of major hazardous waste handlers located within the PSAPCA jurisdiction. The listings identified quantities of compounds that were stored, treated or disposed of at a given location. Of particular concern were RCRA codes D001, ignitable wastes; F001 and F002, spent halogenated solvents; F003 and F005, spent non-halogenated solvents; and Department of Ecology codes WT01 - WT02, toxic wastes; WP01 - WP02, halogenated wastes; and WP03, polycyclic aromatic hydrocarbons. Wastes with RCRA U- and P- codes were reviewed individually to assess their air toxic potential. In general, if the vapor pressure of this material exceeded 0.1 mm Hg and the quantity handled exceeded one metric ton, the material was considered to be a potentially significant air toxic source. Within the limitations of the current hazardous

waste reporting system, this listing proved invaluable in identifying the potential air toxic emissions sources connected with hazardous waste facilities.

The sources identified in Table I were selected from the listing of hazardous waste treatment storage and disposal facilities based upon the quantities and types of RCRA wastes handled. Highest priority was given to facilities with volatile organic wastes or those that handled known toxic wastes. In addition, if a hazardous waste TSDF was believed to be representative of a number of similar facilities, it was given a suitably higher priority for site visitation.

DESCRIPTION OF EMISSION ESTIMATION METHODOLOGIES

As noted previously, the measurement of emissions from non-traditional sources is complicated due to their size and complexity. Large area sources, such as surface impoundments and landfills do not lend themselves to traditional source sampling and monitoring techniques. Field measurement techniques typically require extensive instrumentation or sampling hardware and evaluation of very low concentrations samples, both of which tend to make sampling and analysis expensive and results less reliable. (Cox, et. al., 1984) Field sampling methodology generally fall into three categories: downwind plume wind transect; surface emission measurements; and flux box techniques. The downwind plume transect requires measurements in the plume of gases emitted by the source at various crosswind distances and heights above ground level. An integration of the concentrations of the gases in the plume identifies the total emissions from the source. A large number of samples must be taken of low concentration gases to obtain a result. In addition, actual source strength can only be determined based upon atmospheric measurements which allow the dispersion characteristics of the atmosphere to be determined. Back modeling from the point of measurement to the actual source of emissions is then required.

Measurement of surface emissions also requires extensive field sampling. Typically, sampling heads are located near the surface of the emitting source whether it be surface impoundment or landfill. Though concentrations are somewhat higher in this case, sampling must again be conducted in several locations across the surface in order to insure representative collection of data. (Pellizzari, 1982)

Flux box techniques utilize a temporary cover or box which is placed over the surface to contain emissions at a higher concentration. The gases within the box are then drawn through a sample collection system for subsequent analysis. The flux box has the disadvantage of changing environmental conditions during sampling. Again the sample box must be placed at several spots across the area to ensure representative estimations of emissions.

Because of the cost and complications of such field sampling techniques and the need to analyze and prioritize a large number of sources, EPA has supported development of both theoretical and empirical models to aid in estimation of emissions from area sources under discussion here. In general, these models are of the so called two-film type in which the movement of pollutants is limited by their ability to diffuse through either soil or water and, after release from the surface, through the air. The models address movement of pollutants as affected by concentration and pressure gradient. Over a limited range of conditions and single component systems in laboratory tests the models have proved to be good emissions predictors. However, a number of factors greatly increase the uncertainty in the use of two-film type models.

Waste composition: Often waste composition is not known. Either composition must be determined or emission estimates must be based on literature values or speculation regarding the highly variable composition. The emissions so derived could show considerable error.

Multi-component systems: Wastes often contain several chemical species of concern. Interaction of the species may be non-characteristic in that solubility, vapor concentrations and overall volatility do not change in a predictable manner. Data on the performance of such multi-component systems, especially in the presence of solid, absorbtive materials is very limited.

Biological and Chemical Breakdown: Chemicals deposited in biologically active systems such as landfills and wastewater treatment plants are subject to decomposition and oxidation often resulting in changes in toxicity, solubility and volatility. Chemical reactions may bring about similar results. The extent to which these changes take place can only be assessed by routine sampling and a thorough understanding of the waste treatment system. Basic mass transfer models cannot address these effects.

Clearly there are major uncertainties in preparing emission estimates using simplified models. However, with some additional information much useful information can be gained in a variety of applications. For example, often there is some understanding through routine or special sampling of waste and wastewater composition allowing identification of toxic components. When

toxics are present in low concentrations multi-component effects are to some extent reduced. The assumptions of no chemical or biological breakdown is conservative, since it tends to maximize the predicted emissions, and very close to reality in many aerated treatment systems where removal of volatile components is rapid.

Considering the cost and uncertainties of field sampling techniques, the methods discussed and used in this report provide the best approach for making preliminary emission estimates and prioritizing sources for further investigations of non-traditional toxic emissions.

Selection of Emission Models

To be of value for the purposes of this study, the emission model must 1) represent conditions that exist at various potential sources and 2) be useable in the sense that it does not require unavailable information (a model which relies upon detailed field measurements or arcane data to produce reasonable results is of no time or cost saving benefit). Models must address adequately the principal physical conditions under which emissions are of concern. These include mixtures of liquid wastes, both aqueous and non-aqueous conditions, mixtures of immiscible liquids, volatile liquids spilled on soil surfaces, volatile liquids diffusing from buried sources, and surface impoundments. For the purposes of this study, models were selected for the estimation of emissions of volatile organic materials from the surfaces of liquid water in which the organic was a minor constituent. Models also were selected for surface impoundments in which surface aeration is used. For volatile wastes mixed with solid material, emission models were selected for the case of the landfill where wastes are contained below a permanent or temporary soil cover.

The resources of this study were limited and models were selected which did not require significant amounts of field measurements or laboratory development. Thus site measurements could be limited to those made during a one time site visit with portable instruments. Chemical data was limited to that which could be derived from the literature or any previously completed special studies. Given these general restrictions, data collection efforts at the individual sites were directed toward quantifying the variables necessary to

utilize the selected emission models. The following sections discuss specific models to address emissions from surface impoundment, landfills and waste processing.

Emissions Models for Surface Impoundments

Both publicly owned and industrial wastewater treatment systems normally consist of a series of open impoundments through which the contaminated water passes. Because of the large number of such facilities, estimation of toxic emissions from these sources is especially important.

Emissions of potential toxic materials from surface impoundments are limited by either the influent quantities or the mass transfer opportunities present in the facilities. For most facilities, the actual amounts of entering toxic components have not been fully determined while effluent quantities have been measured to ensure compliance with applicable discharge permits limits. Fortunately, the largest treatment works have completed or are planning influent/effluent analyses allowing improved estimation of the upper limit of the more significant toxic air contaminant sources.

Two other factors can substantively affect the level of toxic materials emitted to the air. First, alternative removal processes are at work especially in treatment facilities. These are primarily removal by biological digestion of the chemicals in secondary treatment and removal and disposal with primary and secondary sludges. For a few potential toxics, a very large fraction of the mass absorbs on the sludge. The emissions of these materials are controlled to the extent sludge digestion gases are treated (incinerated). Second, chlorination of wastewater within the treatment plant actually result in the creation of some toxic constituents though the simultanious chlorination of residual organic compounds.

Unfortunately, except for those cases for which detailed influent/effluent analysis is available, consistent and meaningful assumptions regarding these alternative addition and removal mechanism cannot be made. Consequently emission analysis for treatment facilities of this study are based upon both mass balance and mass transfer limitations. The most conservative estimate

from the perspective of the control agency would be given by the higher of these two values. Studies at METRO West Point and Renton indicated that the volatile toxics of greatest concern were removed, principally in primary and secondary treatment processes, with only a small fraction eliminated through sludge removal. Since sludge digestion gases are subsequently combusted the potential emissions of toxics from this source was considered insignificantly small in this study.

In addition to the available mass of toxic material, emission release rates also are controlled by factors affecting the mass transfer of the component of concern from the wastewater solution to the air. Besides overall exposed surface area of the impoundment other key factors affecting the transfer are wind speed, turbulence of the liquid and the relative volatility and solubility of the chemicals. Based on a review of mass transfer models addressing such factors (U.S.E.P.A., 1984a), ES selected the emission estimation models of Thibodeaux, Parker and Heck with Hwang and Shen simplifications. These models are based upon a two film resistance theory which assigns a separate transfer coefficient for movement of the chemical through the air and liquid phases. The overall transfer coefficient a compound is determined as follows:

$$\frac{1}{K_L} = \frac{1}{k_L} + \frac{1}{Kk_G}$$

where

K_L = overall liquid phase mass transfer coefficient for the compound
k_L = individual liquid phase mass transfer coefficient of the compound
k_G = individual gas phase mass transfer coefficient of the compound, and
K = constant establishing equilibrium between the liquid and air phases.

With the overall mass transfer coefficient so defined, emission estimates are determined from:

$$Q_i = K_L A\, x_i\, MW_i$$

where

Q_i = rate of air emission of compound i;

A = area of impoundment;

x_i = concentration of i in the impoundment liquid; and

MW_i = molecular weight of i.

These equations assume: 1) Concentrations of i in the liquid are relatively low such that Henry's Law applies; 2) the impoundment is a steady state system, and 3) the air concentrations of i are small compared to water concentrations. When Henry's Law applies the equilibrium constant K is essentially the Henry's Law constant (H) for the chemical multiplied by suitable factors to obtain the mole fraction form for K[1]. (Thibodeaux, et. al., 1983)

The individual liquid phase coefficient k_L is dependent on a dimensionless Reynolds roughness value, Re*, which in turn is a function of wind speed. However, at wind speeds below about 4 m/s, there is little effect due to wind resulting in the use of a minimum k_L value of 2.4 cm-hr^{-1} or 0.271 lb-mol-ft^{-2}-hr^{-1}. Since annual average wind speed in the Puget Sound Region is less than 4 m/s, the minimum value was used in all calculations of non-aerated impoundment emissions. Equation used for estimating k_L are shown in Table II.

The individual gas phase transfer coefficient, k_G, is also primarily a function of wind speed and for this work was estimated using the equation of Table II. Also shown in the table, the Schmidt number was estimated using a linear equation based on a simplification suggested by Shen.

Alternative equations were used for k_L and k_G under conditions of mechanical aeration of the impoundment. Individual liquid phase coefficients are highly dependent on aerator power input and efficiency. The gas phase transfer is closely tied to aerator physical parameters (particularly diameter and rotational speed) and the density of the gas of concern. Equations for aerated impoundments also are shown in Table II.

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[1] Typically,

$$K = \frac{H\ (\text{atm-m}^3\text{-mol}^{-1}) \times 10^6\ (\text{g-m}^{-3}\ \text{of solution})}{1\ (\text{atm}) \times MW\ (\text{g-mol}^{-1}\ \text{of solution})}$$

TABLE II
EQUATIONS USED FOR ESTIMATING
EMISSIONS FROM SURFACE IMPOUNDMENTS (U.S.E.P.A., 1984a)

NON-AERATED IMPOUNDMENT

Liquid Phase Coefficient, k_L:

$$k_L = (1.3\ Re^{*\,0.195} - 0.57)\ (MW_{benzene}/MW_i)^{0.5}$$

and

$$Re^* = \frac{7.07 \times 10^{-2}\ (U_{10})^{1.25}}{\nu_a\ \exp\ (56.6/(U_{10}^{0.25}))}$$

if $Re^* < 0.11$, then $K_L = 0.273$ lb-mol-ft^{-2}-hr^{-1}

where

$MW_{benzene}$ = molecular weight of benzene
MW_i = molecular weight of compound i
U_{10} = wind speed in (cm/s) at a height of 10 meters above the water surface
ν_a = kinematic viscosity of air (cm^2/sec)

Gas Phase Coefficient, k_G:

$$k_G = 0.0958\ U^{0.78}\ N_{Sc}^{-0.67}\ d_e^{-0.11}\ \rho/MW_{air}$$

where

U = wind speed in (m/hr)
N_{Sc} = Schmidt number for vapor ($N_{Sc}^{-0.67}$ estimated by :0.81 - 0.00138 MW after Shen)
d_e = effective diameter of the impoundment (m) (estimated by (4 x Area)$^{0.5}$)
ρ = density of air (lb/ft^3)
MW_{air} = molecular weight of air (lb/lb-mole)

TABLE II (cont.)
EQUATIONS USED FOR ESTIMATING
EMISSIONS FROM SURFACE IMPOUNDMENTS

AERATED IMPOUNDMENTS

Liquid Phase Coefficient turbulent zone, $(k_L)_T$:

$$(k_L)_T = \frac{4850\ J\ (P)\ (1.024)^{-20}}{(a_v)(v)} \left[\frac{D_{i,H_2O}}{D_{O_2,H_2O}}\right]^{0.5}$$

where
J = O_2 transfer rating of aerators (abt. 3 lb O_2/hp-hr)
P = Aerator power (rated hp x efficiency)
θ = temperature (^oC)

a_v = surface area per unit volume of surface impoundment (ft^{-1})

v = volume of surface impoundment in the region of effect of aerators (ft^3)

D_{i,H_2O} = diffusion coefficient of compound i in water

D_{O_2,H_2O} = diffusion coefficient of O_2 in water

Gas Phase Coefficient, turbulent zone, $(k_G)_T$:

$$(k_G)_T = 0.00039 \frac{\rho_g\ D_{i,\ air}}{d} (N_{Re})^{1.42} (N_{Fr})^{-0.21} (N_P)^{0.4} (N_{Sc})^{0.5}$$

where
$N_{Re} = \rho_g\ d^2\ \omega/\mu g$ *

$N_{Fr} = d\ \omega^2/g$*

$N_P = P\ g/\rho_L\ d^5\ \omega^3$*

$N_{Sc} = \mu_g/\rho_g\ D_{i,air}$*

and
ρ_g = density of vapor (lb/ft^3)
d^g = impellor diameter (ft)
$D_{i,air}$ = diffusion coefficient of compound i in air (ft^2/hr)

ω = impeller speed
μ_g = absolute gas viscosity
g = gravitational constant
P = power to impeller
ρ_L = density of liquid

* units must be consistent to assure dimensionless results

A critical factor affecting emissions is the Henry's constant (H) for a given material, which indicates the ratio of volatility to solubility. Specifically H is defined in Henry's Law for a two-phase system by:

$$y_i = Hx_i$$

where

y_i = concentration of i in vapor phase; and
x_i = concentration of i in liquid phase

Henry's Law is applicable for ideal solutions which are approximated at low concentrations of solute. It has been shown that for a Henry's constant value greater than 10^{-3} atm-m^3-mol^{-1} mass transfer is essentially controlled by the liquid above so that $K_L = k_L$. For a Henry's constant less than 2×10^{-5} atm-m^3-mol^{-1}, transfer is controlled by the gas phase so that $K_L = k_G$. For intermediate values of H, both coefficients are important and K_L is defined as shown previously.

Because aeration has a much more significant effect on liquid than gas phase mass transfer, it tends to greatly augment the transfer rates of materials that were previously liquid phase limited. As a result, transfer rates of chemicals with high volatility and low solubility (high Henry's constant) are dramatically increased compared to those with a low H value when aeration is introduced.

An example calculation estimating emissions from both aerated and non-aerated surface impoundments is contained in Appendix C.

Modeling of Sewage Treatment Plant Emissions

Because most treatment plants for which emission estimates were to be prepared could not be visited and sampled, it was necessary to assume potential toxic constituent concentrations. Though data from the field sampling activities of this project and well-analyzed plant influents (such as for Renton and West Point) serves as a partial basis, previous EPA analyses of a broad range of priority pollutants in publicly owned treatment works provided a substantial

additional data base to characterize POTW concentrations (USEPA, 1979 and USEPA 1982b). The results of this broad EPA study clearly show the difference in concentrations of potential air toxic chemicals based on the industrial contribution to plant influent.

Detailed review of information on individual facilities showed that most plants included in the EPA study had a substantial industrial component in their service area. Priority pollutant levels approximated or exceeded those at West Point and Renton facilities of METRO which handle the large fraction of the METRO service area industrial load. To provide a better estimate of toxic plant loadings for Puget Sound areas where residential customers were dominant, data were selected from two "residential only" facilities in the EPA study and combined with data from the Chambers Creek and Everett treatment works. The latter two plants have minimal industrial loading, and in each case, some recent compositional information was available. The average of influent values for these four facilities, used as a generic wastewater in preparing estimates for other plants serving residential areas, is shown in Table III.

Publicly owned treatment works included in this emission estimation effort were categorized according to significance of industrial contribution based on discussion with plant operators and PSAPCA. Plants with a clear and significant industrial component in the service area were classified as industrial facilities. Plants which served areas with no or minimal industrial activity were classified non-industrial treatment works. For industrial treatment for which no specific analysis was available, it was necessary to assume influent concentrations also. These concentrations are based on average values of those measured at METRO West Point and Renton facilities.

TABLE III

POLLUTANT CONCENTRATIONS OF GENERIC INFLUENT STREAMS

(micrograms per liter)

	Residential[1]	Industrial[2]
Toluene	3.85	50.6
Tetrachloroethylene	6.82	15.8
Methylene Chloride	3.85	48.7
Bis(2-ethylhexyl)phthalate	5.77	0
Chloroform	2.97	9.8
Trichloroethylene	17.5	12.6
1,1,1-trichloroethane	1.93	0
Ethylbenzene	0.90	8.7
Phenol	0.08	50.2
Di-n-butyl phthalate	0.02	43.4
1,2-trans-dichloroethylene	8.75	0
Benzene	2.81	3.4
Butyl benzyl phthalate	0.01	61.6
Napthlene	0.01	13.7
Diethylphthalate	0	4.5

[1] Specific influent data were available for Chambers Creek and Everett facilities.

[2] Specific influent data were available for METRO-West Point and Renton facilities.

Emission Models for Hazardous Waste and Chemical Process Equipment

Included in this review of non-traditional emissions sources were hazardous waste treatment facilities. The most significant emissions from these plants are associated with the handling and recovery of waste solvents and other wastes which contain significant solvent fractions. Processes in these facilities include decanting or pumping of drummed solvent waste, separation of solvents by gravity and distillation, disposal of still bottom wastes, and storage and drumming of recovered products. Emissions estimation techniques for each of these processes is discussed below.

Transfers of Drummed Waste (Decanting)

Liquid drummed wastes which are consolidated into tank storage result in emissions equivalent to other tank filling operations. Since tank storage is of the fixed roof variety, emissions are equivalent to the equations discussed under the tank storage section. Fugitive emissions for pump transfers are discussed in the section addressing fugitives from process equipment.

Open air drum decanting of liquid and semi-solid waste results in noticeable losses of volatile solvents. Emissions from this process have not been well-documented but were estimated by EPA in relation to landfill solidification processes. Though decanted liquids flow readily to holding tanks, solvent-saturated wastes serve as an emission source until repacked in drums or the solvent is evaporated. Because high solids wastes normally contain about 20 percent solvent, most of which is immediately recovered by decanting, only about 1% of the total waste amount is lost as an air contaminant. This is roughly equivalent to four pounds per drum decanted when the liquid is substantially solvent (Engineering-Science, 1984a)

Tank Storage

Materials stored in tanks in solvent recovery facilities include clean and dirty solvent and solutions or immiscible mixtures of solvents and solvents and water. Although tanks are used primarily for storage they also are used for gravity separation of water/solvent mixtures. Only in the case of the

separation of heavy organics and halocarbon solvents in which the recovery products are covered by a layer of water would emissions from gravity separation processes be reduced compared to normal tank storage. Storage tank emission estimation methods are well documented once waste stream composition is determined and tank geometry is established (EPA, 1982).

Process Equipment Emissions

Besides normal pumps and piping, process equipment at the solvent recovery operations consisted of pot stills, wiped-film evaporators, and distillation columns. Emissions from the column and evaporator will be due to fugitives and vacuum pump exhaust only since these units operate under a vacuum for most solvents. EPA surveys of emissions from solvent recovery operations indicated 3.3 lb/ton of reclaimed solvent is lost as emissions (Engineering-Science, 1985).

Fugitive Emissions

Fugitive leaks occur from pumps, flanges, valves and drums and have been investigated extensively by EPA pursuant to establishing good operating practices for the petroleum processing industry. These factors are applied to solvent processing equipment which follows the procedures of previous analyses of hazardous waste processing equipment prepared by EPA (Engineering-Science, 1985). The specification of the VOC estimates prepared is based on hazardous waste types identified in annual RCRA reports (Washington Department of Ecology, 1983).

Identification of Hazardous Waste Constituents

Under its hazardous waste regulations the U.S. EPA has established a series of codes for identification of hazardous wastes. Some codes identify waste properties, others the waste sources or groups of similar waste compounds, and some refer to off specification chemicals. The Washington Department of Ecology has added to this list several additional wastes identified as dangerous. Non-specific waste codes tell little about the air pollution potential

of the waste since detailed composition is not known. These codes were not developed to assess or track the air pollution potential of a waste but rather to identify the principal hazardous material or property. As a result a waste constituent that may have significant potential to become an air toxic emission may not be noted beyond the original manifest. For example, a corrosive liquid may be assigned a code of D002 based on low pH. The same waste may also contain 1% of a chlorinated solvent but this constituent may not be identified or reported in waste summaries. Since practical inventory efforts must rely upon this summarized waste information, emissions from many waste streams cannot be accurately estimated.

To evaluate the emission potential of wastes of concern, ES obtained copies of WDOE facility reports (WDOE, 1983) so that both waste codes and actual waste descriptions could be reviewed. Based on this information, key wastes codes such as D001 (ignitable wastes), F001-005 (waste solvents), and WP01 (wastes containing volatile organics) were evaluated and categorized as to volatility and the physical nature and likely method of processing of the waste compounds involved.

Landfill Emission Models

Emissions of air toxics from landfills are dramatically affected by such factors as the volume and nature of non-toxic wastes, size and age of the landfill, the soil used for intermediate and final cover and the number and functioning of flares. None of the landfills investigated in this study operated as hazardous waste landfills. However, all are believed to have received some such wastes during their active histories and all continue to receive small quantities of hazardous waste (i.e., household hazardous wastes). All have operated as municipal landfills receiving a wide variety of putrescible materials. As a result the landfills may be considered co-disposal sites with what is believed to be a small but not well defined toxic component to the wastes. Substantial landfill gas flux is evident, particularly at Midway, Cedar Hills and Kent Highlands sites, which carries toxic constituents to the surface to be emitted along with methane, carbon dioxide, and other common landfill gas components. Toxic emissions are

greatly increased when gas generation and movement augment the concentration gradient driven transfer of toxic materials.

Thibodeaux's recommended emission estimation model for landfills with internal gas generation was selected for estimation of net gas flow from the modelled landfill (USEPA, 1984a). In this model, soil diffusion factors are largely overshadowed by net upward gas flow except when gas generation is small or there is a thin porous covering over volatile materials. The net gas velocity must be estimated by other means namely estimating the net gas flux. Table IV illustrates the Thibodeaux equation and terms.

Estimation of the critical gas velocity term were based upon best available gas generation data for municipal disposal sites. For Kent Highlands, (Lockwood, 1985) and Cedar Hills (Schulte, 1985) landfills, specific, though preliminary, gas generation studies have been completed. From waste quantity estimates for other sites, generation rates were estimated based on these studies and general landfill gas generation data.(Baron et. al., 1981) For the entire decomposition life of a typical waste, total gas volume is estimated as approximately $6 ft^3/lb$ of waste. Because the decomposition process takes place over many years, under typical moist, anaerobic conditions, an average gas release rate of 0.15 $ft^3/lb\text{-}yr$ can be assumed. These values combined with landfill mass provide a net flux rate. Using gas composition data (see section Gas Composition), an estimate of total potential air toxics emissions can be made for a given site. An example calculation for emission estimates for codisposal landfills may be found in Appendix C.

Emission from waste in landfills without gas generation (such as newly placed waste or buried materials with small bio-gas generation potential) are limited by the resistance provided by soil and air diffusion. In virtually all cases the overall mass transfer will be limited by soil phase diffusion coefficient so that the emission is estimated by

$$E = k_{soil} \quad C_{ig} \, A \qquad \text{(Spawn and Farino, 1983)}$$

where

E = emission rate (g/sec)

k_{soil} = soil phase diffusion coefficient (cm/sec)

C_{ig} = vapor concentration of compound i in soil or waste pores (g/cm^3)
A = surface area of waste (cm^2)

Clearly the diffusion coefficient and concentration factors are key and because of limited field measurements must be estimated. ES prepared estimates of k_{soil} using the following equation (Farmer, 1978):

$$k_{soil} = \frac{D_{i,air}}{h} \frac{\varepsilon_a^{3.33}}{\varepsilon_t^2}$$

where

$D_{i,air}$ = diffusivity of i in air (cm^2/sec)
h = depth of cover (cm)
ε_t = total soil porosity
ε_a = $\varepsilon_t - \phi\beta$ = air filled soil porosity
ϕ = soil gravimetric moisture (g/g)
β = soil bulk density (g/cm^3)

As may be noticed increasing moisture content tends to reduce k_{soil} and, therefore, emissions due to smaller pore and passage size.

If not known by direct measurement vapor concentration within the pore spaces can be estimated provided the bulk concentration of the material of concern is known:

$$C_{ig} = \frac{W_i \gamma_i P_i MW}{RT}$$

where

W_i = weight percent of compound i in waste
γ_i = activity coefficient of i in waste, normally 1 for hydrocarbons and mixtures of hydrocarbons
P_i = vapor pressure of i (mmHg)

MW = average molecular weight of waste (g/g-mol)
R = universal gas constant (6.24×10^3 mmHg - cm^3/gmol-K)

T = absolute temperature (^{o}K)

The assumption of unity for the activity coefficient is not applicable to aqueous solution and must be evaluated individually from chemical equilibrium data. For the purpose of these estimates it was assumed that emissions occurred from deposited or accumulated organic solution. This serves to give conservative (high) emission estimates.

Flare Emissions

Since most municipal landfill sites have had concerns or problem with odorous gases and horizontal gas migration, gas flares are commonly used to reduce landfill gas pressure and destroy potential odorous compounds. The fraction of the potential gaseous emissions which are released through flares is incinerated resulting in a substantial reduction in emissions of toxic materials. (85 to 95% are typical control efficiencies for such flares when operating.) Reports prepared to estimate impacts of flare emissions on the surrounding land owners indicated about 15% of the flares were self-extinguished each day resulting in a direct release of landfill gas and associated air toxics (Larson and Wineman, 1985). Flow rates for these flares vary greatly depending on location and size and have only limited documentation. However, an average flow of 30 cfm from 4 inch diameter flare pipes has been advanced based on measurement at a limited number of sites. (Larson and Wineman, 1985) Since flow is affected by local landfill pressure, atmospheric pressure, porosity of wastes, well dimensions, and the flare assembly, good characterization of flows will require measurements of individual flares.

Gas flow through the flare system was based on the identified number of flares when available. Otherwise flare numbers were estimated by 1 flare per 4 acres of landfill. This "treated" gas was subtracted from that estimated for the landfill as a whole in estimating toxic emissions.

Gas Composition

Composition of landfill gases is available for the largest landfills in the Puget Sound area which are all being investigated as part of closure or expansion planning. Composition data for these sites are summarized in Table

V. Gas composition for other landfills is based on the average of these measurements.

TABLE IV

TOXIC AIR CONTAMINANT

EMISSION ESTIMATIONS EQUATIONS

FOR LANDFILLS WITH INTERNAL

GAS GENERATION (USEPA, 1982)

$$N_A = \frac{V_y \left(\overset{*}{\rho}_{A1} - \rho_{A1i} \right)}{\exp \left(h \, V_y / D_{A3} \right)^{-1}} + V_y \overset{*}{}_{A1}$$

N_A, mass flux rate

ρ^*_{A1}, conc. of A in sand chamber filled pore spaces

h, depth of fill cover

D_{A3}, effective diffusivity of A within the air-filled soil pore space

V_y, mean gas velocity in pore spaces

ρ_{A1i}, concentration of A at air-soil interface

TABLE V
AVERAGE COMPOSITIONS OF LANDFILL FLARE GASES TOXIC AND PRIORITY POLLUTANT[1]

Compound	Landfill					
	Kent Highlands		Midway		Cedar Hills	
	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)	(ppm)	(mg/m^3)
Acetone	4.81	11.62	0.98	1.16	NR	
1,2-Dichloroethane	0.02	0.08	0.16	0.64	NR	
Carbon Tetrachloride-Benzene	92.06	276.49	43.26	129.92	2.48	8.03
Isooctane	3.2	15.47	0.99	4.78	NR	
Trichloroethylene	3.53	18.66	0.07	0.37	2.42	12.79
Toluene	40.50	151.69	10.25	38.39	35.54	133.11
Octane	3.20	15.44	3.35	16.17	4.12	19.89
Tetrachloroethylene	4.91	52.77	0.77	5.14	4.40	29.37
C_2 Benzene[2]	27.76	120.76	17.48	76.03	5.92	25.75
Hydrogen Cyanide	0.10	0.11	ND	ND	ND	ND
1,1,2,2-Tetrachloro-ethane	ND	ND	ND	ND	NR	
Limonene	30.20	167.96	5.52	30.70	NR	
Hydrogen Sulfide	96.0	135.06	8.95	12.60	ND	ND
Chlorobenzene	ND	ND	ND	ND	NR	
Methylene Chloride	34.33	120.00	1.11	3.88	1.31	4.58
4-Methyl-2-Pentanone	0.08	0.33	0.20	0.83	NR	
2-Butanone	0.40	1.08	0.04	0.11	2.53	6.83
1,1,1-Trichloroethane	0.04	0.23	0.04	0.23	2.92	13.91
Chloroethane	0.01	0.03	0.01	0.03	NR	
Chloroform	ND	ND	ND	ND	NR	
1,1-Dichloroethane	0.17	0.25	ND	ND	NR	
1,2-Dichlorethylene	0.16	0.54	0.05	0.18	0.64	1.96
1,1-Dichloroethylene	0.06	0.21	0.05	0.21	4.19	15.08
1,2-Dichloropropane	0.02	0.05	Trace		NR	
Vinyl Chloride	0.04	0.10	Trace		NR	

ND - Not Detected, Detection limit = 0.15 mg/m^3 @ 49L
NR - Not Reported

[1] Data from Parametrix, 1984; Powell, 1985.

[2] C_2 Benzenes include Xylene Isomers & Ethyl Benzene

RESULTS OF EMISSION ESTIMATES

Emission estimates were prepared for the non-traditional sources listed in Table I. In each case, emissions were based on throughput values, volumes or other key data obtained from field testing, special study reports, regulatory agencies, the facility operator or their consultants. In cases where appropriate detailed information was not available, estimates were based on data for similar sources or estimates prepared from the previously noted information sources and standard references.

This section discusses by category the results of these emission evaluations. However a word should be provided about the general level of confidence attributable to the various estimates. The categorization of emission estimate confidence level generally can be summarized using the criteria defined for federal emission factor development.

Emission Factor Rating	Basis of Factor
A	Stack test results
B	Documented material balance
C	Recognized emission factor, material balance estimates
D	Engineering judgement using available data
E	Guess

Virtually none of the non-traditional sources that were subjects of this investigation had been source tested regarding any emissions, much less toxic air contaminants. As a result there are no factors with A ratings. Only the METRO-West Point and Renton facilities qualify as having well-documented material balance information. However, there is such variability and inconsistencies in these results that a "B" rating would be difficult to justify. Other facilities including those sampled during this study have limited

material balance data or other significant analytical questions which limit confidence to C levels or less. The following sections discuss emission estimation results on a category-by-category basis:

Publicly Owned Wastewater Treatment Works

The large POTWs of METRO-West Point and Renton and Tacoma Central and Northend have substantial potential emissions due to industrial influent (assumed in the case of the Tacoma facilities, to be equivalent in concentration to the Renton works). However, since the primary treatment facilities have no aeration, emissions are small due to mass transfer limitations. As a result, the Renton facility has by far the largest emissions of all POTWs. The West Point facility with a very large total throughput of toxics (about 70 Tons/Year) emits very little due to the undisturbed surface of the primary clarifier. (METRO, 1984a and METRO, 1984b) Mass transfer coefficients are very low for this impoundment which has a low velocity flow and is well-protected from wind. Of course some portion of the toxics which pass through these plants will be emitted from the receiving waters.

The effect of aeration is to increase the overall transfer coefficient by a factor of perhaps 300 for liquid phase-limited (volatile, sparingly soluable) chemicals and about 4-6 times for highly soluable, low volatility chemicals. As a result any aerated impoundment rapidly strips out those chemicals with Henry's constants exceeding about 10^{-4} atm-mol-m^{-3}. Table VI lists treatment plants by total toxic emission based on identified or estimated wastewater concentrations. As may be noted small throughput plants with secondary treatment can emit relatively significant levels of volatile compounds. Breakdowns of these total emissions into toxic components are found for each plant in the Tables of Appendix A. Review of this information shows the largest single compound release to be 2.8 Ton/Year of methylene chloride from the METRO-Renton facility.

TABLE VI

TOTAL IDENTIFIED TOXIC EMISSIONS

FROM SELECTED POTWS

Plant Name	Wastewater Throughput (MGD)	Toxic Emissions[1] (Ton/Year)
Primary Treatment Plants		
Bremerton	3.6	0.005
Des Moines	6.0	0.010
Edmonds	10.0	0.012
Lakehaven (Lakota)	3.5	0.005
Lynnwood	4.5	0.006
Maryville	4.5	0.006
METRO, Alki	10.0	0.012
METRO, Carkeek Park	3.5	0.005
METRO, Richmond Beach	3.2	0.005
METRO, West Point	125.0	0.377
Snohomish	1.0	0.005
Southwest Suburban (Miller Creek)	3.6	0.005
Southwest Suburban (Salmon Creek)	3.5	0.005
Tacoma Central	38.0	0.107
Tacoma Northend	10.0	0.028
Tacoma Western Slopes	3.0	0.005
		0.603
Secondary Treatment Plants		
Alderwood Water District	3.0	0.258
Brownsville	4.8	0.510
Chambers Creek	3.5	0.800

TABLE VI (cont.)

Enumclaw	2.5	0.211
Everett	31.0	1.210
Lake Stevens	0.5	0.056
Lakehaven (Redondo)	3.6	0.310
METRO-Renton	50.0	8.648
Puyallup	8.0	0.688
Sumner	2.0	0.172
Westside	0.75	0.087
		12.950

[1] Total toxic emissions include the following chemical species: benzene; bis (2-ethylhexyl) phthalate; butyl phthalate; chloroform; diethyl phthallate; di-n-butyl phthallate; ethyl benzene; methylene chloride; naphthalene; phenol; tetrachloroethylene; toluene; 1,2-transdichloroethylene; 1,1,1 trichloroethane; trichloroethylene; 1,1,2,2 tetrachloroethane and 1,1,2,2 tetrachloroethene. Listings of estimated emissions of each of these chemicals for each facility are located in Appendix A.

Industrial Wastewater Treatment Facilities

Each industrial wastewater treatment facility handles specific varieties of wastes usually with only moderate change in composition and flow. Occasionally, however, plant operational problems cause a major shift in wastewater chemistry or volumes to be treated. Such swings in operation are much greater and occur more rapidly than those experienced by POTWs which normally are not dramatically affected by changes in operation of a single customer.

Because of the nearly unique composition of industrial wastewater treatment streams it was not practical to expand emission estimation beyond those sites visited except where the process activity and the resulting wastewater are essentially identical to those of a source examined previously. As a result ES' analysis is limited to four industrial wastewater treatment operations shown in Table VII.

Each of the pulp mill operations required treatment of water contaminated with wood pulp, lignin, and paper bleach chemicals. Each treatment process analyzed differed from the other, though all employed forced aeration of the neutralized and clarified influent. The Scott Paper Company plant used conventional activated sludge (using a diffused air system) followed by secondary clarifation prior to release. Weyerhaeuser performed aeration in large aeration lagoons equipped with surface aerators. The Simpson-Tacoma (formerly St. Regis) plant treats wastewater using the UNOX system with pure oxygen aeration.

Similar levels of aeration power were supplied to the Scott Paper and Weyerhaeuser aerators and this fact was used to estimate emissions from the bubbling system employed by Scott. The chemical stripping ability of the Scott plant was assumed to be equal to that provided by equivalent oxygen transfer by surface aerators for which emission estimation models have been derived. The UNOX system supplies only slightly greater amounts of oxygen for aeration than are needed by the treatment processes. Secondary treatment is covered resulting in very limited emissions from this process.

TABLE VII

ESTIMATED EMISSION

FROM

SELECTED INDUSTRIAL WASTEWATER

TREATMENT FACILITIES (Ton/Year)

Air Contaminant	Company/Source			
	Scott Paper/ Sec. Treatment	Weyerhaeuser/ Lagoon System	Simpson-Tacoma UNOX	Wyckoff/ Water Evaporation
Chloroform	14.6	35 - 492[1]	2.3[2]	
Ethyl Benzene				0.0005
Styrene				0.0040
Toluene	3.6			
O-xylene				0.0005
M-xylene				0.0005
Pentachlorophenol				0.5[3]

1 Range of values is presented because 492 ton value is based on a single sample and believed to be non-representative. The sample appears to have been taken during a batch release of chemicals. Refer to page 40 for further discussion.

2 Assumes 0.1 mg/l chloroform lost to atmosphere and 15 million gallons/day throughput

3 Worst case estimate - assumes water saturated with pentachlorophenol

Because of the chlorine-based bleach chemicals in the influent, there is a tendency to form chlorinated organic compound as was evidenced by chloroform in samples taken from the influent of the Scott and Weyerhaeuser. This was the only volatile air toxicant identified in the analysis performed by ES except for toluene in the Scott sample. However, chloroform levels were relatively high, 13 mg/l at Weyerhaeuser and 0.8 mg/l at Scott. No chloroform was detected in the effluent streams. Table VII indicates annual emission levels associated with these facilities. The limited emissions of Simpson-Tacoma are due to the limited stripping action of the UNOX system. The high levels at Weyerhaeuser are probably due to batch release of bleach chemicals and therefore may not be representative of the influent stream. This can only be verified with additional sampling and analysis. For comparison, chloroform emission were estimated based on previously prepared emission factors for uncontrolled pulp and paper mills (EPA, 1984b). Annual chloroform emission are 35 tons using this value and Weyerhaeuser pulp production. Both values are included in Tables S-1 and VII recognizing that the larger value is probably not representative of routine emissions.

The wastewater treatment system was also reviewed at the Wyckoff Company. To avoid discharges of contaminated water, Wyckoff continuously evaporates water collected from wood treating activities and the rainfall run-off control system. Water from treated timber is separated from immiscible oils and the treating materials, creosote and pentachlorophenol, and circulated through an open spray tank. If necessary two heated ventilated tanks are also used.

The total quantity of water treated annually by Wyckoff is small, little more than one million gallons, but all contaminants therein are released to the air. Because of limited funds, Wyckoff water analyses were limited to volatiles which resulted in the emission estimates shown in Table VII. Unfortunately, many of the important materials handled by Wyckoff are non-volatiles which must be extracted from the water samples and analyzed. These include the cresols, cresylic acids and pentachlorophenol.

Saturating the wastewater with pentachlorophenol would result in about one thousand pounds of the product being emitted in a year. However, the cresols and related acids are highly soluble and substantial tonnages can be

TABLE VIII
ESTIMATED TOXIC AIR EMISSIONS FROM SELECTED
LANDFILL SITES

	Cedar Hills	Midway	Kent Highlands	Hidden Valley	Olympic View	Ollalla	Hansville
Esitmated steady state annual gas volume ($10^6 ft^3/yr$)	1679	480	1800	802	800	200	31
Estimated % through flares	14	82	88	10	90	0	0
Net Control efficiency (%)	13	74	79	9	81	0	0
Emissions of Toxic Components (Ton/Year)							
Toluene	6.30	0.15	21.79	2.80	0.58	0.77	0.11
Tetrachloroethylene	1.13	0.02	0.62	0.47	0.10	0.13	0.02
Methylene Chloride	0.21	0.02	1.41	0.69	0.14	0.19	0.03
Chloroform	ND	ND	ND	ND	ND	ND	ND
Trichloroethylene	0.66	0.12	0.22	0.46	0.10	0.12	0.02
1,1,1-Trichloroethane	ND	0.00	0.00	0.00	0.00	0.00	0.00
1,2 Dichloroethyene	0.79	0.00	0.00	0.13	0.03	0.04	0.00
Benzene/CCl_4	0.37	0.50	3.26	2.81	0.58	0.77	0.11
1,1 Dichloroethane	0.12	0.00	0.00	0.02	0.00	0.01	0.00
Hydrogen Sulfide	ND	0.03	1.59	0.80	0.17	0.22	0.03
Limonene	NR	0.11	1.98	1.51	0.31	0.41	0.06
Xylenes	1.21	0.30	1.42	1.59	0.33	0.44	0.07
	10.79	1.25	12.29	11.28	2.34	3.10	0.49

dissolved in the annual wastewater throughput. An estimate of the emission for these materials will be equal to their average concentration in the wastewater multiplied by annual throughput of 1,104,000 gallons per year. (DaRos, et. al., 1982)

Landfills

As discussed previously landfill emissions occur from buried wastes and from newly applied waste which still resides on the landfill surface. In general emissions are diffusion controlled, however, where there is putrescible waste the considerable emissions of methane and carbon dioxide carry with them any toxic constituent greatly increasing the toxic emissions also. Since the large landfills studied here all received municipal waste, landfill gas generation would dominate the emissions mechanisms.

Table VIII identifies the anticipated annual gas emission rate from several landfills in the Puget Sound Area. These values are based upon both detailed studies and evaluations using general estimating procedures (Schulte, 1985; Lockwood, 1985; Dehn, 1985; Powell, 1985; Dunlap, 1985; Miller, 1985; Parametrix, 1984). The toxic emission are proportional to overall landfill gas flow and are estimated based on gas composition data obtained in support of closure and expansion plans. The composition data is accurate for samples taken; however, it is clear from samples at various well sites that there is great variation between wells making average compositions only useful in the sense of this broad inventory (Larson and Wineman, 1985). No meaningful average gas composition has been determined for any facility at this time. Averages of available data were used to estimate emissions from unmeasured sites.

As noted previously, a fraction of landfill gas is released through flares to control noxious gases and odors. The amount that is emitted by this route has only been measured at one site and great variability was noted. However, an average value of 30 cfm was measured and is used for making estimations of this emission component. A control efficiency of 90% is assumed for the flare when operating. (Powell, 1985) Although flare efficiencies have been

measured both above and below this value, the 90% value was selected because non-methane organics are found only in small fractions so that combustion is not complicated by heavier organic fuels. Smokiness or other indications of diffusion flame burning and associated high emissions were not observed. Refinement of flare gas flow rates is needed to improve the emission estimate but would require, as a minimum, an extensive flare testing program.

Hazardous Waste Facilities Treatment, Storage and Disposal Facilities

As noted previously, emission estimates for waste solvent handling were prepared based upon factors developed through a recent survey of state control agencies with regard to solvent recovery operations (Engineering-Science, 1985). These factors were applied to operations at the Chemical Processors, Inc., Georgetown plant and the Lilyblad Petroleum plant. Processing was similar at the two plants, though Chemical Processors, Inc. (Chem-Pro) handled a broad variety of materials while Lilyblad Petroleum essentially recovered lacquer thinners and related paint solvents. Figure 1 illustrates the basic material flow through these facilities. Emission estimates also were prepared for six other hazardous waste treatment storage and disposal facilities based on waste type and quantity handled and process activities. Processes were identified from RCRA Part A data and discussions with Department of Ecology and facility personnel. Waste amounts and types were based solely on DOE records. (WDOE, 1984 and WDOE, 1985) Emission estimates for these RCRA facilities are summarized in Table IX.

It should be noted that the totals of Table IX are based on the best estimation of the nature and volatility of the coded waste. Also the apparent fraction of waste in water or other material was addressed when possible. However, there is little specific waste data in RCRA or WDOE summary records which makes species determination possible except for wastes codes that define single species or for wastes that may have been specifically noted. These are a small minority. Thus the estimates of Table IX include material identified as hazardous but not necessarily an air toxic of concern. Some detail on toxic species is included in hazardous waste report, implicitly and explicitly. For example, Lilyblad handles quantities of perchloroethylene and 1,1,1-trichloroethane which are identified by name and Crosby and Overton

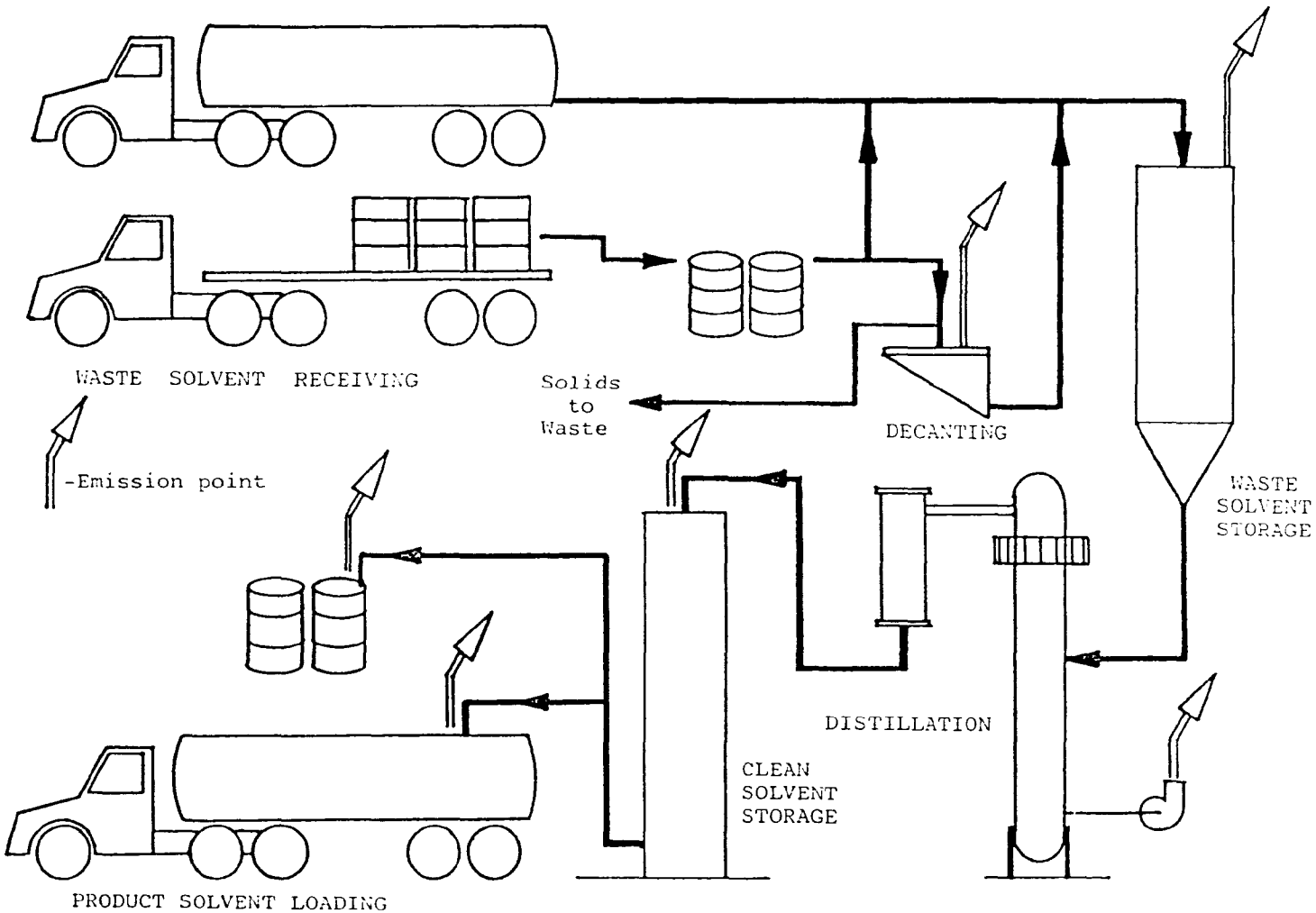

Figure 1. General process flow diagram for solvent recovery operations.

TABLE IX
AIR TOXIC EMISSION ESTIMATES FOR
SELECTED HAZARDOUS WASTE
TREATMENT, STORAGE, AND DISPOSAL FACILITIES

Plant Name	Processes	Potential Toxic Air Contaminant	Total Estimated Emissions (T/Y)	Estimated Toxic Emissions (T/Y)
Chemical Processors, Inc.	Solvent storage (drums and tanks) Solvent transfers Drum decanting Solvent distillation	Chlorinated solvents, benzene, xylenes	2.89	1.09
Lilyblad Petroleum	Solvent storage (drums and tanks) Solvent transfers Solvent distillation	Chlorinated solvents, xylenes	8.66	1.42
Northwest Enviro Services	Waste storage (drums and tanks) Treatment (separation) in tanks Solidification	Halogenated and non-halogenated solvents	5.09	2.38
Boeing Plant 2	Waste storage (drums and tanks)	Halogenated and non-halogentated solvents	0.40	0.2
Boeing Renton	Waste storage (drums and tanks)	Halogenated and non-halogentated solvents Oily water	0.40	0.1
Crosby & Overton	Waste storage (drums and tanks) Treatment (separations) in tanks	Gasoline and water, oily water, paint sludges	0.75	0.10
Safety Kleen - Auburn	Transfers of dirty solvents (drums, small container, small tanks)	Halogenated and non-halogented solvents	0.35	0.25
Safety Kleen - Renton	Transfer of dirty solvents (drums, small containers, small tanks)	Halogenated and non-halogenated solvents	0.30	0.22

handle gasoline contaminated waters which contain benzene and xylenes, but these clearly specified quantities are small and associated emissions are insignificant.

If the generalization is made that halogenated solvents, aromatic solvents (including benzene, toluene, and xylenes), and wastes listed as toxics (WT) by Washington Department of Ecology are all potential air toxics, an estimate of toxic emissions can be prepared from available summarized data. This estimate is included as the last column of Table IX.

Superfund Sites

Emissions were evaluated for three currently active Superfund sites for which clean up plans are now being developed. The Western Processing site located in Kent, Washington has already undergone surface clean-up, however, the substantial subsurface accumulations of waste are still to be removed. They are widespread under the site with most within nine feet of the surface. The Tacoma Tar Pits are the results of waste disposal from coal/oil gasification processing. Residual tars were land disposed for a period of more than 25 years resulting in substantial soil concentrations and some small surface impoundments of tar. Queen City Farms is a waste disposal area which received a variety of waste solvents, oils, polychlorinated biphenyls and metals. Periodically solvents and oils were burned presumably to reduce the volume of waste in three small ponds. As a result of years of disposal, pond areas are heavily contaminated with organic and metal sludges. Surrounding surface and subsoils also are contaminated.

Western Processing

Emission estimates were prepared for two separate categories of toxics: volatile and polycyclic aromatic hydrocarbons. As with other sites there is considerable variation from point-to-point within the site making it difficult to generalize about concentrations of specific compounds. Compounds were grouped in two categories, volatiles and polycyclic aromatic hydrocarbons, in summary reports. (USEPA, 1985a)

Emissions were based on the most ambitious clean up alternative; removal of 300,000 cubic yards of contaminated soil. Removal is estimated to take 400 days over twenty months. Under this plan, soil is to be removed to a depth of 15 feet over most of the site resulting in an exposed excavation face area of approximately 6,500 square feet. For the purposes of estimation, it was assumed that the entire face is excavated each day resulting in the maximum contaminated soil exposure. Appropriate excavation procedures could reduce this daily exposure of new surface by 75%. Complete volatilization of toxic materials in a newly exposed soil layer was assumed within the first day with emissions from the remaining buried waste then restricted by this layer. The thickness of this layer was determined by equating the loss by evaporation of all of the compound in the layer to the loss through the layer by diffusion. Thus layer thickness increases as volatility increases. This method over predicts consistently by a factor of less than two and avoids the need to evaluate daily emissions using time dependent models and the errors resulting from an assumed constant thickness. Emission estimates are based on average volatility and diffusion factors for the two compound groupings. Though this lack of detail is unfortunate, overall emissions estimates of less than 0.1 lb/day make such detail unnecessary. For comparison current annual emissions for the site also were determined. These values are based on the waste being primarily located between six and nine feet below the surface thus approximating a waste landfill with a six foot thick cap. Because the concentrations of these buried wastes are relative low over most of the site current emissions are exceedingly small; less than 0.01 lb/day.

Tacoma Tar Pits

The Tacoma Tar Pits remedial action is not as far along in planning as Western Processing though site contamination has been characterized. (Applied Geotechnology, 1985) As a result excavation parameters are not available. Assuming this option to be viable, an analysis similar to that conducted for Western Processing was completed. For excavation rates comparable to those planned for Western Processing, a higher daily emission rate would be anticipated at the Tar Pits (though still less than 0.25 lb/day) due principally to higher soil concentrations of toxics. Extreme concentrations of tar and tar saturated soils will likely cause short-term emissions to increase greatly for

some days. Concentrations of toxics in pond sediment are one to two orders of magnitude greater than soil values on which overall estimates are based. Thus special attention should be paid to site activities when pond/pit excavation is planned.

Queen City Farms

The clean-up of Queen City Farms will be a small undertaking compared to the previously described sites. Only 22,000 cubic yards of material have been identified as contaminated. Again excavation plans are not well developed, however, removal of waste over the period of two months would be in line with other removal plans. Wastes reside in three separate areas: pond waters, pond sediments and soils below and between the ponds. Sediment volumes represent about one-fourth the total volume but have concentrations of toxics 50 times that of surrounding soils.(Hart, Crowser, 1985) The five to ten days during which these materials are removed represent the period of greatest concern for this site. However, even during this period average emissions should remain relatively low. Concentrations of toxics in impounded waters are estimated to cause emissions of volatiles of nearly 0.8 lbs/day. These emissions will dominate overall site emission even during removal efforts.

CONCLUSION

Toxic emissions from the facilities addressed in this report total to approximately 100 tons assuming the high emission estimate attributed to Weyerhaeuser-Everett is not representative of normal operation. After careful verification of our sample analysis, ES suggests additional sampling be conducted at this plant to determine the effect of batch chemical releases on overall wastewater quality. Major emitters also are wastewater treatment facilities both industrial and municipal. Large municipal landfills form a second group with emissions roughly equivalent to median wastewater treatment facilities. Clearly of lesser interest among those facilities reviewed are hazardous waste handlers and clean-up sites where relatively low annual throughputs (solvent recovery) or low volatility wastes limit emissions.

In preparing such estimates our limited understanding of the make-up of materials being handled and, in the case of landfills, the total amount of waste, greatly restrict the ability to make precise estimates. However, many of these limitations also apply to traditional inventories even after source inspections. Improving emission estimates, especially for the larger sources, will require collection of additional field data. For example, routine analysis of paper and pulp mill wastewater influent and effluent would improve estimates; however, verification of emissions will have to come by way of source test due to biological and sedimentary removal mechanisms. Improving landfill estimates will require flare system measurements and detailed estimates of potential gas production in addition to documentation of toxic composition. Because of the variability of wastes handled by TSDFs, several samplings of weekly or monthly waste records would serve to both characterize and indicate the variability in waste streams. Superfund clean-up activities need be addressed only on a case-by-case basis. Since Superfund sites have generally been in existence for sometime, the high volatility organics are no longer present. The remaining high molecular weight materials will be slow emitters.

Ultimately improvement in emissions estimates will rely upon continued investigations of sources of interest in order to collect and refine pertinent information. It is hoped this initial review provides a basis for prioritizing the work ahead.

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Appendix A

Air Toxic Emission Estimates
for
Publicly Owned Treatment Works

(Refer to Table III of main text
for assumed influent concentrations)

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Bremerton

Location: Kitsap County

Average Daily Flow: 3.8 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE
DIETHYL PHTHALATE

Total emissions of all constituents estimated as less than 0.005 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Lynnwood

Location: King County

Average Daily Flow: 4.5 MGD

Estimated Annual Emissions for Specified Compounds

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE
DIETHYL PHTHALATE

Total emissions of all constituents estimated as less than 0.005 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Snohomish

Location: Snohomish County

Average Daily Flow: 3.5 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE
DIETHYL PHTHALATE

Total emissions of all constituents estimated as less than 0.005 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: METRO, West Point Treatment Plant

Location: Discovery Park, Seattle, King County, Washington

Average Daily Flow: 125 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.114
TETRACHLOROETHYLENE	0.040
METHYLENE CHLORIDE	0.110
BIS (2-ETHYLHEXYL) PHTHALATE	ND
CHLOROFORM	0.020
TRICHLOROETHYLENE	0.030
1,1,1-TRICHLOROETHANE	ND
ETHYLBENZENE	0.020
PHENOL	0.004
DI-N-BUTYL PHTHALATE	0.001
1,2-TRANS-DICHLOROETHYLENE	ND
BENZENE	0.007
BUTYL BENZYL PHTHALATE	0.002
NAPHTHALENE	0.028
DIETHYL PHTHALATE	0.001
	0.377

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Everett

Location: City of Everett, Snohomish County

Average Daily Flow: 31 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	ND
TETRACHLOROETHYLENE	ND
METHYLENE CHLORIDE	ND
BIS (2-ETHYLHEXYL) PHTHALATE	ND
CHLOROFORM	ND
TRICHLOROETHYLENE	ND
1,1,1-TRICHLOROETHANE	ND
ETHYLBENZENE	ND
PHENOL	0.61 [1]/
DI-N-BUTYL PHTHALATE	ND
1,2-TRANS-DICHLOROETHYLENE	ND
BENZENE	ND
BUTYL BENZYL PHTHALATE	ND
NAPHTHALENE	ND
1,1,2,2-TETRACHLOROETHANE	0.30
1,1,2,2 TETRACHLOROETHENE	0.30
	1.21

[1]/ value based on 99% removal of phenol found typical. Influent/effluent analysis of "total phenols" (1) of 12/84 would indicate potential emissions of 2.03 T/Y.

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Chambers Creek

Location: Pierce County

Average Daily Flow: 3.5 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.01
TETRACHLOROETHYLENE	ND
METHYLENE CHLORIDE	ND
BIS (2-ETHYLHEXYL) PHTHALATE	ND
CHLOROFORM	ND
TRICHLOROETHYLENE	0.20
1,1,1-TRICHLOROETHANE	ND
ETHYLBENZENE	ND
PHENOL	ND
DI-N-BUTYL PHTHALATE	ND
1,2-TRANS-DICHLOROETHYLENE	0.14
BENZENE	ND
BUTYL BENZYL PHTHALATE	ND
NAPHTHALENE	ND
ACETONE	0.15
ISOPROPANOL	0.10
DIMETHYL DISULFIDE	0.10
TETRAHYDROFURAN	0.10
	0.80

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Brownsville

Location: Kitsap County

Average Daily Flow: 4.8 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.03
TETRACHLOROETHYLENE	0.04
METHYLENE CHLORIDE	0.02
BIS (2-ETHYLHEXYL) PHTHALATE	0.03
CHLOROFORM	0.01
TRICHLOROETHYLENE	0.13
1,1,1-TRICHLOROETHANE	0.01
ETHYLBENZENE	0.01
PHENOL	0.04
DI-N-BUTYL PHTHALATE	0.03
1,2-TRANS-DICHLOROETHYLENE	0.06
BENZENE	0.02
BUTYL BENZYL PHTHALATE	0.04
NAPHTHALENE	0.01
DIETHYL PHTHALATE	0.03
	0.51

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Des Moines Sewage District

Location: King County

Average Daily Flow: 6.0 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE

TETRACHLOROETHYLENE

METHYLENE CHLORIDE

BIS (2-ETHYLHEXYL)
PHTHALATE

CHLOROFORM

TRICHLOROETHYLENE

1,1,1-TRICHLOROETHANE

ETHYLBENZENE

PHENOL

DI-N-BUTYL PHTHALATE

1,2-TRANS-DICHLOROETHYLENE

BENZENE

BUTYL BENZYL PHTHALATE

NAPHTHALENE

Total emissions of all constituents estimated as less than 0.010 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Tacoma Central

Location: City of Tacoma, Pierce County

Average Daily Flow: 38 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.033
TETRACHLOROETHYLENE	0.012
METHYLENE CHLORIDE	0.033
BIS (2-ETHYLHEXYL) PHTHALATE	ND
CHLOROFORM	0.006
TRICHLOROETHYLENE	0.010
1,1,1-TRICHLOROETHANE	ND
ETHYLBENZENE	0.006
PHENOL	0.001
DI-N-BUTYL PHTHALATE	0.001
1,2-TRANS-DICHLOROETHYLENE	ND
BENZENE	0.002
BUTYL BENZYL PHTHALATE	0.001
NAPHTHALENE	0.002
	0.107

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: METRO - Renton Sewage Treatment Plant

Location: Renton, King County, Washington

Average Daily Flow: 50 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.721
TETRACHLOROETHYLENE	1.522
METHYLENE CHLORIDE	2.823
BIS (2-ETHYLHEXYL) PHTHALATE	ND
CHLOROFORM	0.224
TRICHLOROETHYLENE	1.689
1,1,1-TRICHLOROETHANE	ND
ETHYLBENZENE	0.139
PHENOL	0.163
DI-N-BUTYL PHTHALATE	0.102
1,2-TRANS-DICHLOROETHYLENE	ND
BENZENE	0.196
BUTYL BENZYL PHTHALATE	0.138
NAPHTHALENE	ND
DIETHYLPHTHALATE	0.066
1,2-DIBROMOETHANE	0.745
DI-OCTYL PHATHALATE	0.120
	8.648

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Puyallup

Location:

Average Daily Flow: 8 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.048
TETRACHLOROETHYLENE	0.085
METHYLENE CHLORIDE	0.048
BIS (2-ETHYLHEXYL) PHTHALATE	0.072
CHLOROFORM	0.037
TRICHLOROETHYLENE	0.218
1,1,1-TRICHLOROETHANE	0.024
ETHYLBENZENE	0.011
PHENOL	0.001
DI-N-BUTYL PHTHALATE	-----
1,2-TRANS-DICHLOROETHYLENE	0.109
BENZENE	0.035
BUTYL BENZYL PHTHALATE	-----
NAPHTHALENE	-----
	0.688

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Sumner Sewage Treatment Plant

Location: Pierce County, Washington

Average Daily Flow: 2.0 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.012
TETRACHLOROETHYLENE	0.021
METHYLENE CHLORIDE	0.012
BIS (2-ETHYLHEXYL) PHTHALATE	0.018
CHLOROFORM	0.007
TRICHLOROETHYLENE	0.055
1,1,1-TRICHLOROETHANE	0.006
ETHYLBENZENE	0.003
PHENOL	-----
DI-N-BUTYL PHTHALATE	-----
1,2-TRANS-DICHLOROETHYLENE	0.027
BENZENE	0.009
BUTYL BENZYL PHTHALATE	-----
NAPHTHALENE	-----
	0.172

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Westside Sewage District

Location: Pierce County, Washington

Average Daily Flow: 0.75 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.005
TETRACHLOROETHYLENE	0.008
METHYLENE CHLORIDE	0.005
BIS (2-ETHYLHEXYL) PHTHALATE	0.008
CHLOROFORM	0.003
TRICHLOROETHYLENE	0.021
1,1,1-TRICHLOROETHANE	0.003
ETHYLBENZENE	0.002
PHENOL	0.006
DI-N-BUTYL PHTHALATE	0.006
1,2-TRANS-DICHLOROETHYLENE	0.010
BENZENE	0.003
BUTYL BENZYL PHTHALATE	0.005
NAPHTHALENE	0.002
	0.087

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Edmonds Sewage Treatment Plant

Location: Snohomish County, Washington

Average Daily Flow: 10 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.0008
TETRACHLOROETHYLENE	0.0014
METHYLENE CHLORIDE	0.0008
BIS (2-ETHYLHEXYL) PHTHALATE	0.0012
CHLOROFORM	0.0006
TRICHLOROETHYLENE	0.0035
1,1,1-TRICHLOROETHANE	0.0004
ETHYLBENZENE	0.0002
PHENOL	0.0004
DI-N-BUTYL PHTHALATE	0.0004
1,2-TRANS-DICHLOROETHYLENE	0.0008
BENZENE	0.0006
BUTYL BENZYL PHTHALATE	0.0005
NAPHTHALENE	0.0002
	0.0118

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Lakehaven Sewage District (Lakota)

Location: King County, Washington

Average Daily Flow: 3.5 MGD

Estimated Annual Emissions for Specified Compounds

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE

Total emissions of all constituents estimated as less than 0.005 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Marysville Sewage Treatment Plant

Location: Snohomish County, Washington

Average Daily Flow: 4.5 MGD

Estimated Annual Emissions for Specified Compounds

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE

Total emissions of all constituents estimated as less than 0.006 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: METRO, Alki

Location: King County, Washington

Average Daily Flow: 10 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.0008
TETRACHLOROETHYLENE	0.0014
METHYLENE CHLORIDE	0.0008
BIS (2-ETHYLHEXYL) PHTHALATE	0.0012
CHLOROFORM	0.0006
TRICHLOROETHYLENE	0.0035
1,1,1-TRICHLOROETHANE	0.0004
ETHYLBENZENE	0.0002
PHENOL	0.0004
DI-N-BUTYL PHTHALATE	0.0004
1,2-TRANS-DICHLOROETHYLENE	0.0008
BENZENE	0.0006
BUTYL BENZYL PHTHALATE	0.0005
NAPHTHALENE	0.0002
	0.0118

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: METRO, Carkeek Park

Location: King County, Washington

Average Daily Flow: 3.5 MGD

Estimated Annual Emissions for Specified Compounds

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE

Total emission of all constituents estimated as less than 0.005 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: METRO, Richmond Beach

Location: King County, Washington

Average Daily Flow: 3.2 MGD

Estimated Annual Emissions for Specified Compounds

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE

Total emissions of all constituents estimated as less than 0.005 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Lake Stevens Sewage Treatment Plant

Location: Snohomish County, Washington

Average Daily Flow: 0.5 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.003
TETRACHLOROETHYLENE	0.005
METHYLENE CHLORIDE	0.003
BIS (2-ETHYLHEXYL) PHTHALATE	0.005
CHLOROFORM	0.002
TRICHLOROETHYLENE	0.014
1,1,1-TRICHLOROETHANE	0.002
ETHYLBENZENE	0.001
PHENOL	0.004
DI-N-BUTYL PHTHALATE	0.004
1,2-TRANS-DICHLOROETHYLENE	0.007
BENZENE	0.002
BUTYL BENZYL PHTHALATE	0.003
NAPHTHALENE	0.001
	0.056

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Southwest Suburban (Salmon Creek)

Location: King County, Washington

Average Daily Flow: 3.5 MGD

Estimated Annual Emissions for Specified Compounds

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE

Total emissions of all constituents estimated as less than 0.005 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Tacoma Northend

Location: Pierce County, Washington

Average Daily Flow: 10 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.009
TETRACHLOROETHYLENE	0.003
METHYLENE CHLORIDE	0.009
BIS (2-ETHYLHEXYL) PHTHALATE	ND
CHLOROFORM	0.002
TRICHLOROETHYLENE	0.003
1,1,1-TRICHLOROETHANE	ND
ETHYLBENZENE	0.002
PHENOL	-----
DI-N-BUTYL PHTHALATE	-----
1,2-TRANS-DICHLOROETHYLENE	ND
BENZENE	-----
BUTYL BENZYL PHTHALATE	-----
NAPHTHALENE	-----
	0.028

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Alderwood Water District

Location: Snohomish County, Washington

Average Daily Flow: 3.0 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.018
TETRACHLOROETHYLENE	0.032
METHYLENE CHLORIDE	0.018
BIS (2-ETHYLHEXYL) PHTHALATE	0.027
CHLOROFORM	0.014
TRICHLOROETHYLENE	0.082
1,1,1-TRICHLOROETHANE	0.009
ETHYLBENZENE	0.004
PHENOL	-----
DI-N-BUTYL PHTHALATE	-----
1,2-TRANS-DICHLOROETHYLENE	0.041
BENZENE	0.013
BUTYL BENZYL PHTHALATE	-----
NAPHTHALENE	-----
	0.258

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Southwest Suburban (Miller Creek)

Location: King County, Washington

Average Daily Flow: 3.8 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE

Total emissions of all constituents estimated as less than 0.005 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Enumclaw

Location: King County, Washington

Average Daily Flow: 2.46 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.015
TETRACHLOROETHYLENE	0.026
METHYLENE CHLORIDE	0.015
BIS (2-ETHYLHEXYL) PHTHALATE	0.022
CHLOROFORM	0.011
TRICHLOROETHYLENE	0.067
1,1,1-TRICHLOROETHANE	0.007
ETHYLBENZENE	0.003
PHENOL	-----
DI-N-BUTYL PHTHALATE	-----
1,2-TRANS-DICHLOROETHYLENE	0.034
BENZENE	0.011
BUTYL BENZYL PHTHALATE	-----
NAPHTHALENE	-----
	0.211

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Lakehaven (Redondo)

Location: King County, Washington

Average Daily Flow: 3.61 MGD

Estimated Annual Emissions for Specified Compounds (Ton/Year)

TOLUENE	0.022
TETRACHLOROETHYLENE	0.039
METHYLENE CHLORIDE	0.022
BIS (2-ETHYLHEXYL) PHTHALATE	0.032
CHLOROFORM	0.017
TRICHLOROETHYLENE	0.098
1,1,1-TRICHLOROETHANE	0.011
ETHYLBENZENE	0.005
PHENOL	-----
DI-N-BUTYL PHTHALATE	-----
1,2-TRANS-DICHLOROETHYLENE	0.049
BENZENE	0.016
BUTYL BENZYL PHTHALATE	-----
NAPHTHALENE	-----
	0.310

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Tacoma (Western Slopes)

Location: Pierce County, Washington

Average Daily Flow: 3 MGD

Estimated Annual Emissions for Specified Compounds

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE

Total emissions of all constituents estimated as less than 0.005 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Snohomish

Location: Snohomish County, Washington

Average Daily Flow: 1.0 MGD

Estimated Annual Emissions for Specified Compounds

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE

Total emissions of all constituents estimated as less than 0.005 Ton/Year

Publicly Owned Treatment Works
Air Toxic Emission Estimate

Facility Name: Lynnwood
Location: Snohomish County, Washington

Average Daily Flow: 4.5 MGD

Estimated Annual Emissions for Specified Compounds

TOLUENE
TETRACHLOROETHYLENE
METHYLENE CHLORIDE
BIS (2-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
DI-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE

Total emissions of all constituents estimated as less than 0.006 Ton/Year

Publicly Owned Treatment Works

Air Toxic Emission Estimate

Facility Name: Bremerton

Location: Kitsap County, Washington

Average Daily Flow: 3.58 MGD

Estimated Annual Emissions for Specified Compounds

TOLUENE
TETRACHLOROETHYLENE
NETHYLENE CHLORIDE
BIS (Z-ETHYLHEXYL)
PHTHALATE
CHLOROFORM
TRICHLOROETHYLENE
1,1,1-TRICHLOROETHANE
ETHYLBENZENE
PHENOL
Dl-N-BUTYL PHTHALATE
1,2-TRANS-DICHLOROETHYLENE
BENZENE
BUTYL BENZYL PHTHALATE
NAPHTHALENE

Total emissions of all constituents estimated as less than 0.005 Ton/Year

Appendix B

Discussion of Site Visits to Selected Non-Traditional Sources of Air Toxic Emissions

Discussion of Site Visits and Emissions Estimation for Selected Non-Traditional Sources

The following are summarizations of investigations of individual facilities selected from lists provided by Puget Sound Air Pollution Control Agency (PSAPCA) as potential air toxic emission sources. Summaries are based on data provided by PSAPCA, telephone converation with source operators and managers, actual site visitation, field measurements, and other investigations, such as, pretreatment studies remedial investigation/feasibility studies and sampling and analysis data. Selection of these sources was not based necessarily on their being the largest or most complicated but on their overall significance based upon size, potential toxicity of emissions, or the extent to which they represented other similar facilities within the Puget Sound jurisdictional area.

METRO West Point Sewage Treatment Plant

METRO West Point Treatment facility is the largest sewage treatment plan in the area and provides primary treatment for some 600,000 residential and 300 industrial users. Primary treatment only is carried out at the plant. This s conducted in 12 rectangular primary sedimentation tanks, each about 38 by 254 feet in size. Thus some 116 thousand square feet of wastewater are exposed at all times. Since these are sedimentation tanks there is not aeration or agitation resulting in minimum potential for volatilization of dissolved gases. After removal of the solids the primary effluent is disposed of via a submarine outfall into Puget Sound. Recovered solids are treated in heated anerobic digesters with by product methane being used for heating purposes.

Pretreatment studies conducted by METRO for the West Point Facilities indicated a broad variety of organic compounds that are on current priority pollutant lists. Total influent of these materials to the West Point Plant is on the order of 350 pounds per day making the facility a maximum of 70 ton per year toxic source. In general, a relatively small fraction of most of the priority pollutants identified were related to specific industrial activities.

Inclusion of the West Point Facility was not due to a particularly high specific emission level, but primarily addresses its large total throughput, some 125 mission gallons per day during the dry season. This large flow rate combined with the identified organic loadings indicated that the West Point Facility could be a substantial source of toxic compounds.

The West Point facility was visited on July 10, 1985 by S.A. Freeburn (ES), Dana Davoli (EPA) and Fred Austin (PSAPCA). Samples of influent were taken, with the assistance of Mr. Ed Babick, at the coarse grit structure. Effluent samples were taken after primary sedimentation just prior to the chlorination channel. The surfaces of the primary sedimentation tanks are very well protected from wind due to open wall and roof structures surrounding the tanks and to the surface of the wastewater being three feet below adjacent walkways. Since these tanks are 9.5 feet deep diffusion of air toxics through the relatively still water will be a principal limiting factor to emissions, especially of volatiles. Sludge removed from primary sedimentation is digested and off gases are used to power three IC engines. Toxics that are removed with the sludge and are subsequently stripped during digestion should be essentially eliminated by passage through the engines.

The METRO Renton Sewage Treatment Plant

The METRO Renton Treatment Plant provides sewage treatment for a population of about 265 thousand people. The design capacity of the plant is 36 million gallons a day though construction is now underway to expand the capacity to 72 million gallons per day, average dry weather flow. Actual current throughput is about 50 MGD. After screening, the influent passes into the preaeration tank where some fine grit is separated. From the preaeration tanks, the influent passes into primary sedimentation tanks where solids are removed. Primary sedimentation is completed in eight rectangular tanks with solids being removed and sent to the West Point Facility via a 12 inch diameter sludge force main and the Elliott Bay interceptor. After primary sedimentation, the sewage liquid is mixed with activated sludge from the secondary sedimentation tanks and aerated. The aerated liquid is then fed to eight 100 foot diameter secondary sedimentation tanks. Because of the secondary treatment (activated sludge) at the Renton Facility, the potential

air emissions are increased over the primary treatment plant at West Point since emission can occur from the preaeration tank, primary sedimentation tanks, the aeration tanks, the secondary sedimentation tanks, as well as the chlorine contact channel prior to release into the Duwamish River. Of these sources, the aeration tanks are by far the most significant.

Though the total amount of the toxic chemicals entering the facility as determined under the Toxic and Pretreatment Planning Study is less than that for the West Point Facility, the increased exposure of wastewater in the aeration activity increased potential specific emission of volatiles dramatically. In addition, since the Renton facility is planned for expansion and is representative of a large number of facilities using activated sludge it was included as an important site visitation facility.

The Renton facility was visited on July 11, 1985 by S.A. Freeburn (ES) and David Kircher (PSAPCA). After a brief plant tour and discussion with Mr. Bill Burwell, wastewater samples for volatiles analysis were taken at the preaeration tank, after primary sedimentation, and after chlorination. The preaeration water surface is highly agitated though the overall area is relatively small. Like the METRO West Point facility, Renton's primary sedimentation tank are well protected from wind by protective barriers, roof and sidewalk and walls elevated about three feet above the water surface.

Aeration is accomplished by blowing air into the secondary treatment tanks. Oxygen content is controlled by throttling blower inlets. After aeration and secondary clarification the wastewater flows through a 900 foot long chlorine contact channel. Flow in the channel was technically turbulent but surface mixing was minimal.

The Everett Sewage Treatment Plant

The Everett treatment works rely upon aerated lagoons for secondary treatment. Wastewater is processed in primary screening which is followed by aeration in basins. After aeration wastewater passes through polishing ponds before final chlorination and release. There are approximately 192 cres of cells at the Everett Treatment works. Thirty acres are utilized for aeration purposes.

Thus there are some 1.3 million square feet of agitated impoundment surfaces from which air toxicants can be emitted. Though the Everett Facility has a dry weathered flow of only 11 to 12 million gallons per day, this large aeration surface would promote the removal of significant quantity of volatile organics from the influent wastewater.

Priority pollutant sampling and analysis was completed for both influent and effluent under wet weather flow conditions. (Baird, 1985) Dry weather studies were to be completed with summer.

The Everett facility was visited on July 9, 1985 by S.A. Freeburn (ES), Dave Kircher (PSAPCA), and Bill Ingram (DOE). Mr. Carl Baird explained facility operations and assisted in gathering of VOA samples. Samples were taken of influent (through an access manhole to the influent sewer line), of influent to the oxidation pond, and the effluent just prior to the chlorination.

Only the influent and final effluent sample were analyzed for volatiles. The only significant levels were for toluene in the influent at 0.2 mg/l. It was not evident in the effluent. This analysis is supported by the Everett analyses serving to support treatability studies. These showed exceedingly low values of 1,1,2,2 tetrachloroethane and phenol as the only significant priorty pollutants.

Chambers Creek Sewage Treatment Plant

Chambers Creek Sewage Treatment Plant is a new facility which is currently operating at about one-fourth its design capacity of 12 million gallons per day. Primary clarifiers are used to separate solids and cover approximately 14 thousand square feet. These are followed by an activated sludge system utilizing submerged turbine agitation with air introduced under the propeller. After activated sludge treatment, wastewaters are moved to a secondary clarifier and then to chlorine contactors. Aerobic digestion is used to reduce sludges with this process taking place in floating dome covered tanks. Two Dissolved Air Flotation units will be used for final separation and removal of solids. The Chamber Creek Facility is very near the median size treatment plant for the Puget Sound area. In addition, its utilization of

activated sludge for secondary treatment is typical of most plants in this size range. It was selected as a good representative facility of perhaps a dozen other plants in the Puget Sound jurisdicational area which have very limited industrial waste streams. A minimal amount of information was available on expected organic content of the wastewaters treated, however.

The Chambers Creek Treatment Plant was visited on July 8, 1985 by S.A. Freeburn (ES) and Dave Kircher (PSAPCA). Larry McCaffrey, Facility Manager aided in sample collection and a tour of the facility. Samples were taken at the grit tanks, after primary settling and prior to chlorination. The second and third sample locations were taken from compositors. Analysis showed little volatile content except 0.2 mg/l methylene chloride in the effluent. Subsequently, more comprehensive analysis showed the following pollutant levels used in the emission analysis (Thompson, 1985):

Chemical	Concentrations (mg/l)	
	Influent	Effluent
Chloroform	0.002	0.003
Perchloroethylene	0.004	0.004
Trichloroethylene	0.039	0.001
Toluene	0.002	0.001
Trans 1,2 Dichloroethylene	0.028	0.001
Tetrahydrofuran	0.020	ND
Acetone	0.030	ND

Flow through the facility averages 3.5 MGD.

Western Processing Superfund Site

Western Processing was a recycling center for hazardous materials, primarily solvents and used soils. Through many years of operation the ground under and around the Western Processing site became contaminated by the hazardous materials that were handled there. As a result, both the groundwater under the site and the air were subject to contamination by the waste materials.

Superfund activities have resulted in a cleanup of the surface of the site during which time some ambient air measurements were taken using a portable organic vapor analyzer. Though these measurements were not intended to be comprehensive in nature they generally showed that ambient VOC levels were essentially background at boundary locations to the plant. No other detailed monitoring of the ambient air concentrations around the plant has been completed.

Plans are now being developed for the removal of the remaining contaminated materials at Western Processing. Because the soils are contaminated, there will be a potential industrial health hazard and elevation of ambient VOC concentratins during the excavation and removal process. The degree of potential exposure and the length of time of emission has not been determined due to tha lack of a completed plan. Removal of all contaminated materials should eliminate any potential hazard due to air toxicants from this site.

Though orginially scheduled for a site visitation Western Processing was not inspected as part of project field activities due to schedule difficulties. No sampling was planned. Since extensive field investigation and planning of remedial action alternatives for this site have been completed emissions could be reasonably estimated based on detailed field data and assuming the most comprehensive clean-up (removal) program. (Site data from the "Feasibiltiy Study for Subsurface Cleanup" (USEPA, March, 1985) was used exclusively for emission potential evaluation).

Lilyblad Petroleum

Lilyblad Petroleum's primary business is the marketing of solvents and the recycling and recovery of waste solvent materials using vacuum distillation. A wiped film vaccum still is in operation processing approximately 400 gallons per day. The primary recovered product is lacquer thinner. The lacquer thinner has four main components: 1. aromatic hydrocarbons; 2. aliphatic hydrocarbons; 3. ketones and; 4. alcohols. Lilyblad is regulated under RCRA as a treatment and storage facility. Emission from this type of facility are

primarily related to transfers of solvents between drums and still, transfer of still bottoms and their disposal, and fugitive emissions from the still and drums in storage.

The Lilyblad facility was typical of numerous small solvent recovery recycling facilities. However, Lilyblad is unusual in that such a large proportion of the handled products is lacquer thinner with lesser recovery of other solvents. Overall there is a very limited variety of products recovered.

During the plant visit by S.A. Freeburn (ES), Dave Kircher (PSAPCA) and Bill Ingraham (DOE), Mr. Ralph Juris of Lilyblad indicated much solvent is received in drums, though a few large customers deliver in bulk. For these Lilyblad maintains dedicated tank storage otherwise solvents must be consolidated from drums to the solvent still feed tank. Recovered solvent was pumped to storage for redrumming. None of the operations or storage tanks were equipped with control devices.

Because of the uncertainity with regard to process wastes and limited resources available RCRA reporting of waste quanitites was used in estimating emissions. General emission estimates based on a solvent recovery emission survey was used to make estimates.

Hidden Valley Sanitary Landfill

The Hidden Valley Landfill is an active site with no final cover in place at this time. It currently received residential trash and garbage which is placed in the landfill in 12 to 15 foot lifts. These received approximately two feet of inorganic mineral soil cover. Since the site has been in operation for more than 15 years there is limited information about the types of waste that were deposited there in years prior to 1975. It is believed that a variety of industrial waste may have been deposited in tha landfill prior to its operation by Land Recovery Incorporated. The Hidden Valley site has been the source of numerous complaints regarding odors which are traced to

emissions of gas from the landfill. Currently gas is vented through installation of temporary perforated gas vents four to eight feet below the soil surface. The emitted gases are then burned in flares mounted on top of the perforated tubes. Flaring continues until such time as the flare extinguishes itself at which time tubes are removed and vent holes are covered over. The emission of gases from the sides of the landfill is used as an indicator for the installatin of venting tubes. Gases from the Hidden Valley Landfill were recently analyzed for composition, however, results are not yet available.

The Hidden Valley site was visited on July 11, 1985 by S.A. Freeburn (ES), Dave Kircher (PSAPCA), and Bill Ingraham (WDOE). Starr Dehn, CH_2M-Hill, identified current operational procedures and answered question related to emission potential. Hidden Valley has very rocky soils for use as intermediate cover which would not appear to significantly impede gas flow under the present level of generation. Approximately eight acres are new at final grades though not capped.

Since emissions of toxics are closely tied to internal gas generation data, waste mass was obtained. Estimates of four million tons in waste were verified. All flares appeared to be approximately four inch pipes. No data was available regarding flare flow rates of gas composition. Since flares could not be extinguished, no gas samples were taken. No data was available on the amount or composition of toxic materials still being received at Hidden Valley.

Tacoma Tar Pits

The Tacoma Tar Pits is the site of an old coal gasification facility. Coal tars produced during the gasification process were disposed of on site and now mostly found at subsurface locations though some are exposed resulting in the name of the site. The tar has been in place for more than 20 years. In addition to the concerns over the toxicity of the coal tar material, the surface soils in the area demonstrate a high metals content possibly due to

metal recycling activities that have been carried out at the location since the demise of the coal gasification operations. There are on site two ponds which fill seasonally with water and this water is in contact with the coal tar itself. Though coal tar constituents are of concern (chiefly polynuclear aromatics materials) they are of relatively low volatility and, in the coal tar matrix, cannot readily be emitted to the atmosphere. Emission of the waste may be increased due to the presence of the pond water.

As a Superfund site considerable data have been collected regarding the Tacoma Tar Pits. At present, data exist regarding the soil concentrations of some of the wastes, the composition of the tar pit itself, and the composition of organics in the pond water. In addition, there are maps indicating the affected areas. As in the case of the Queen City Farms the Tacoma Tar Pits represent a source of toxic yet low volatility waste materials. Ambient emission under current conditions would be expected to be minimal. However, as removal operations precede, these may become a significance source of air contaminants until such time as excavation is completed.

The Tacoma Tar Pit site was visited on July 11, 1985 for a general inspection by S.A. Freeburn (ES), Dave Kircher (PSAPCA) and Bill Ingraham (WDOE). No sampling was planned. Since weather had been dry the Tar Pits examined contained no water and the tarry surface was exposed. No odor was evident. Though soft and viscous the tar obviously contains significant mineral material. The tar surface appeared somewhat sealed by a tar crust and soil combination. In general there were no signs of air emissions of any type. Emissions during excavation and removal of contaminated soils were estimated based on contamination reports and probable excavation rates.

Wyckoff Incorporated

Wyckoff is a wood treating company which utilized creosote and pentachlorophenol for the preservation of wood, primarily wood poles. The wood treating process is conducted in pressure retorts during which water is removed from the poles being treated and replaced with preservatives. Because

of zero discharge requirements for its wastewater, Wyckoff and other wood treating facilities evaporate collected wastewaters to eliminate the need for discharge. As a result, Wyckoff operates two heated and one unheated evaporation tank, which contains sprays near the top to increase evaporation capabilties. This evaporation process is thought to result also in the evaporation of organic constituents of the waste water including treating oil, creosote compounds, and pentachlorophenol. Because the Wyckoff wastewater treatment facility is representative of a number of other wood treating plants in the Puget Sound area it is included here.

The Wyckoff plant was visited on July 8, 1985 by S.A. Freeburn (ES), Dave Kircher (PSAPCA) and Glynis Stumpf (WDOE) and on July 10, 1985 by Freeburn, Dana Davoli (EPA), and Fred Austin (PSAPCA). On the original schedule date of July 8, it was found the plant had not been operating and the latter visits was scheduled. On July 10, process water was about to enter the wastewater processing system from the gravity separation tanks. The sampling need actually caused Wyckoff to release a small quantity of the water prior to normal release time. Thus waters might have somewhat greater organic content than would otherwise be the case. Samples were taken as the water from the gravity separation tanks entered the oil water separator. Samples also were taken from the feed line to the sprays of the open top cooling water tank as well as the surface of the water in this tank. Since operation had been limited the cooling water in the tank had been circulating without additional input of organics for several days. The toxic content of this water would be expected to be at a minimum. The heated evaporation tanks were not in operation.

Samples indicated a limited selection of volatiles. (Extractables were not done due to limited budget and opportunities to obtain analyses through others means). No volatiles were found in spray water as might be expect under the circumstances. Gravity separator waters contained these volatiles:

Ethyl benzene	0.1 mg/l
O-Xylene	0.1 mg/l
M-Xylene	0.1 mg/l
Styrene	0.8 mg/l

Because of the limited quantity of water treated this composition does not represent a significant emission source. It is emphasized that these are estimates of volatiles only.

Chemical Processors Incorporated
Georgetown Facility

Chemical Processors Incorporated is a waste recycling facility dealing in the recycling and reclaimation of solvents and waste oils, and the treatment of hazardous wastewaters. The Georgetown Facility specialized in solvent recovery by distillation and the disposal of hazardous waste in drums. Solvents are received primarily in drums and transferred to a receiving tank. From this tank, solvents are transferred to the still where solvent reclaimation is completed. A pot-type still distillation column and wiped film evaporator are used to reclaim a wide variety of solvent materials. Clean solvents are returned to drums or tank and still bottoms are solidified and placed in drums for disposal at a hazardous waste landfill. Chem-Pro also received and processes hazardous waste for direct disposal in landfills for its customers. These liquids are mixed with solidification agents in an on-site mixer. Currently, all hazardous wastes are disposed of at the Arlington, Oregon hazardous waste disposal site. Chemical Processors has no on site wastewater treatment capabilities per se, however, all run off waters are captured and tested prior to release to the sewer system. Some wastewaters with identified minor organic contamination are processed through the still condensor water cooling tower. The result is some air stripping of organics of the treated wastewater. The Chemical Processors facility at Georgetown was recommended for inclusion in the site visitation lists, since it represents one of the largest hazardous waste processing facilities in the Seattle-Tacoma area.

The Chem-Pro Georgetown plant was visited on July 10, 1985 by S.A. Freeburn (ES), Fred Austin (PSAPCA) and Dana Davoli (EPA). Mr. Dennis Stephani represented Chem-Pro. Distillation and storage equipment was reviewed. Some decanting operations were in process in which solids were separated from liquids to be reclaimed. After a period of exposure in the atmosphere, solids and entrained liquids were further solidified for disposal. No emission

control equipment was apparent. All product tank storage was underground. Tank storage of dirty solvent and all drum storage is above ground. Chem-Pro received about 1100 drums per month. As a result of discussions with Chem-Pro it was decided to obtain throughput data from Washington State Department of Ecology. No samples were taken at Chem-Pro.

The Cedar Hills Landfill

The Cedar Hill Landfill is one of the largest solid wastes disposal facilities in the Puget Sound area and in two years, with the closure of the Kent Highlands Landfill will received essentially all waste from the Seattle area. Because Cedar Hills has been in operation for more than 20 years, it predates many of the regulations restricting the disposal of several common hazardous wastes, and it may have received industrial and commerical waste that could result in the emission of toxic materials. It currently received some commercial and light industrial waste, but mostly residential wastes. Cedar Hills also has been the source of routine odor complaints which are associated with the emission of landfill gas in the area. Flaring of this gas is a common practice. Some composition data is available based on samples of the vapor in the leachate collection system. There have been limited investigations of subterranean gas transport in the last year. Because of it's large size and the indications that it will be receiving very much greater amounts of waste, the Cedar Hills was included for site visitation. (Swafford, 1985)

Cedar Hills was visited on July 12, 1985 by S.A. Freeburn (ES), Fred Austin (PSAPCA), and Dana Davoli (EPA, Region 10). Shirley Jurgenson of King County Solid Waste and Ed Powell fo CH_2M-Hill assisted in describing site activites and collection of samples. Two samples of landfill gas were taken from wells placed in the landfill for the purpose. Gases were collected on activated charcoal tubes. Cedar Hills had already collected and analyzed gas samples for the purpose of identifying gas production and odor sources. Gas composition is summarized in Table V of the report body.

Flares were observed but no indications of problem operations were observed. Flow rate information for flares is not available.

Midway Landfill

Midway Landfill is a Superfund site under investigation because of a substantial business, commerical, industrial waste received over the last several years. Significant quantities of industrial waste are known to have been deposited within the Midway Landfill. In addition, significant quantities of residential waste have also been deposited resulting in significant gas production such that flaring of gas is common. Data on the geseous emissions from the Midway site as well as the types of waste that have been disposed of in the site are being developed as part of the Superfund feasibility study.

Midway was not visited due to schedule difficulties. Fortunately, however, as a result of the substantial investigations of the site related to closure plan development, more emission estimation information had been prepared than for other sites. Results of emissions estimates were compared to impact study results and flare throughput data for reasonableness.

Weyerhaeuser Company

The Weyerhaeuser Kraft Paper mill in Everett operates a large aerated stabilization basin for treatment of wastewaters. The sixty acre lagoon allows for settling of solids and aeration of liquid effluent through use of twenty-seven aerators. Effluent sources include the bleach plant, scrubber water discharge, and mill drainage. As a result the wastewater contain primarily bleach chemicals and lignin. Chlorinated hydrocarbons are an obvious potential air toxic form this combinations.

Because of the large surface area and aeration, the potential for emissions of volatiles is significant. Because of the large number of Kraft mills in Region 10, analysis of the emissions was believe to have particularily broad application and should be included in site visitation and evaluation plans.

Weyerhaeuser, Everett was visited on July 9, 1985 by S.A. Freeburn (ES), David Kircher (PSAPCA) and Bill Ingrahm (WDOE). Harold Rupert represented Weyerhaeuser, identified sampling location and responded to questions

regarding wastewater processing. Samples were taken from liquid surfaces at the entrance to the equalization pond (influent), the entrance of the following oxidation pond, and at the outfall (effluent). Aerators were not operating during the visit period. Odor was evident.

One sample from the influent showed a high chloroform content of 13 mg/l. Outfall measurement showed the value to be down to 0.06 mg/l. With the assumption of no biological breakdown for chloroform, emission of this quantity of chloroform would represent a substantial toxic sources.

Scott Paper Company

Scott Paper Company, Everett operates a sulphite paper mill. To treat wastewater from these operations, a primary clarifier is used followed by a secondary treatment system. The primary clarifer receives boiler - ash and paper fiber - contaminated waters. After removal of these solids, the wastewater is neutralized with slaked lime and sent to aeration cells. Also introduced at this point are wastes from pulp bleaching, sludge dewatering, pulp mill overflow, and sludge incineration. After bubbled aeration, the wastewater is clarified again and released. Dewatered sludge is incinerated on site.

Priority pollutant scans of wastewaters were conducted five years ago and though this data is not recent, the process at Scott has not been changed. Organics in pulping wastes and chlorine in bleach waste can form chlorinated emissions, chloroform, for example. Chlorinated organics used in processing are released to secondary treatment also.

The Scott facility being representative of other sulphite mills and the potential for emissions of toxic chlorinated organics it was believed it should be included for site visitation and evaluation.

Scott Paper Company was visited on July 9, 1985, by S.A. Freeburn (ES), Dave Kircher (PSAPCA) and Bill Ingram (WDOE). Scott was represented by Tim Bechtel. Mr. Bechtel arranged for VOA samples to be taken from untreated influent, neutralized influent and treated effluent. The plant has

significant excess capacity and only half the aeration capability was operating during the visit. Aeration is by air diffusion on the bottom of 20 feet deep tanks. All plant operations were normal and flow was measured at 15 MGD during sampling. Samples taken at the influent showed 0.8 mg/1 of chloroform which was not detected in effluent samples. However 0.2 mg/1 of toluene was measured in effluent water.

APPENDIX C

Example Emission Calculations

GENERAL EMISSION ESTIMATION EQUATIONS FOR SURFACE IMPOUNDMENTS

Emissions from surface impoundment can be estimated by the following equation:

$$Q_i = 18E\text{-}9\ (K_L)C_{iL}\ A$$

where 18E-9 = dimension correction constant

K_L = overal mass transfer coefficient in (lb-mole/ft^2-hr)

C_{iL} = concentration of pollutant i in (μg/l)

A = area of impoundment in (ft^2)

Q_i = emission rate of compound i in (lb/hr)

K_L is the mass transfer coefficient considering mass transfer limited by diffusion through liquid and gas phase bounary layers. K_L is defined as follows:

$$K_L = (k_L^{-1} + (keq\ k_G)^{-1})^{-1}$$

where k_L = liquid phase mass transfer coefficient

k_G = gas phase mass transfer coefficient

keq = equivalency factor = Henry's constant (atm-m^3/mol) for compound i x 55555.

The constant 55555. converts Henry's constant in units shown to mole fraction form (dimensionless) and assumes that the solution is essentially water at pressure of one atmosphere.

$$\frac{1{,}000{,}000\ \frac{g}{m^3}}{18\ \frac{g}{g\text{-mole}} \cdot 1\ atm} = 55{,}555.\ \frac{mol}{atm\text{-}m^3}$$

A key simplification can be made based on the magnitude of Henry's constant for a given material:

for $H \geq 10^{-3}$ resistance to mass transfer is 95+% controlled by liquid phase resistance and $K_L \simeq k_L$

for $H \leq 2 \times 10^{-5}$ resistance to mass transfer is 95+% controlled by gas phase and $K_L \simeq k_g$

for $2 \times 10^{-5} < H < 10^{-3}$ resistance to mass transfer is controlled by both phases and $K_L = (k_L^{-1} + (55555Hk_G)^{-1})^{-1}$

CALCULATING INDIVIDUAL MASS TRANSFER COEFFICIENTS

The individual liquid and gas phase mass transfer coefficients, k_L and k_G, are largely functions of liquid and vapor turbulence and are influenced by wind speed and forced aeration.

NON-AERATED SURFACE IMPOUNDMENTS

For non-aerated impoundments, ambient wind speed has a significant effect. Individual k values can be estimated using equations developed by Thibodeaux, et.al. (U.S. EPA, 1984a).

$$k_L = (1.3\ Re^{*0.195} - 0.57)\ (MW\ benzene/MWi)^{0.5}$$

where MW benzene = molecular weight of benzene

MWi = molecular weight of compound i

for $0.11 \leq Re^* \leq 102$ and Re^* is defined as:

$$\frac{0.0707\ U^{1.25}}{\nu_a \exp(56.6/U^{0.25})}$$

where U = wind speed at 10 m above surface in cm/sec

ν_a = kinematic viscosity of air (cm^2/sec) = 0.14 at 15°C

Combining these k_L is estimated by:

$$(1.3\ [0.707\ U^{1.25}/\exp\ (56.6/U^{0.25})]^{0.195} - 0.57)(MW\ benzene/MW_i)^{0.5}$$

If Re^* is less than 0.11, k_L is estimated at 0.27 lb-mole/ft^2-hr. k_L is plotted for various wind speeds on the following Figure C-1.

k_G is estimated by the equation from Table II modified for wind velocities measured in cm/sec.

$$k_G = 0.0958\ (U \times 36)^{0.78}\ N_{Sc}^{-0.67}\ d_e^{-0.11}\ \frac{\rho_{air}}{MW_{air}}$$

where N_{Sc} = Schmidt No.

d_e = equivalent diameter of the impoundment (m) = $(4 \cdot Area/\pi)^{0.5}$

ρ_{air} = density of air = 0.075 lb/ft^3

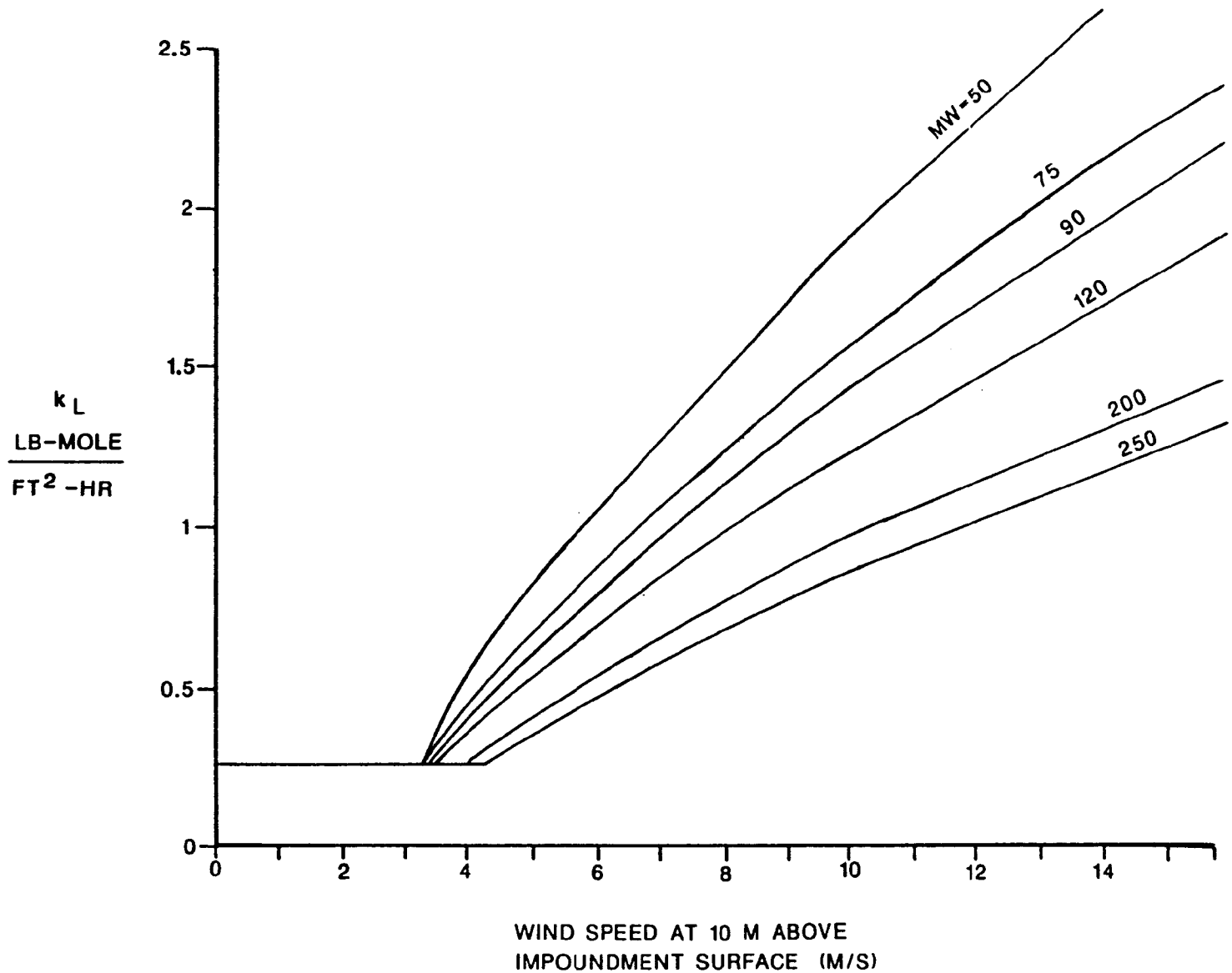
2.5
2
1.5
1
0.5
0
k_L
LB-MOLE
FT^2 -HR
MW=50
75
90
120
200
250
0
2
4
6
8
10
12
14
WIND SPEED AT 10 M ABOVE
IMPOUNDMENT SURFACE (M/S)

FIGURE C-1

Assuming mean values for air properties and an estimator for $N_{Sc}^{-0.67}$ based on Hwang (U.S. EPA, 1984a)

$$k_G = U^{-0.78} A^{-0.055} (0.00325 - 5.54E\text{-}6\ MWi)$$

where U = wind speed (cm/sec)

A = impoundment area (m^2)

MWi = molecular weight of compound i

k_G = gas phase transfer coefficient in lb-mol/ft^2-hr

For typical average wind speeds (2-6 m/s), impoundment areas (100 - 10,000 m^2), and molecular weights (50 - 250), k_G varies between 0.0696 and 0.336 lb-mole/ft^2-hr.

AERATED SURFACE IMPOUNDMENTS

For aerated impoundments, both turbulent and non-turbulent surface conditions exist. Non-turbulent or convective areas are treated as non-aerated surface impoundments. For turbulent conditions, the liquid phase transfer coefficient $(k_L)_T$ is estimated by:

$$(k_L)_T = \frac{4850\ J\ (POWER)\ (1.024)^{\theta-20}}{(a_V)\ (V)} \left[\frac{D_{i,\ H_2O}}{D_{O_2,\ H_2O}}\right]^{0.5}$$

where J = oxygen transfer coefficient (average value from literature is about 3 lb O_2/hp-hr)

POWER = hp x efficiency of motor

θ = temperature (°C)

a_V = surface area per unit volume (ft^{-1})

V = impoundment volume in region of effect of aerators (ft^3)

D_{i,H_2O} = diffusion coefficient of i in water

D_{O_2,H_2O} = diffusion coefficient of O_2 in water ≈ 7.1E-4 cm_2/sec

The gas phase mass transfer coeffienct for turbulent areas is estimated by

$$(k_G)_T = 0.00039 \frac{\rho_g D_{i,air}}{d} N_{Re}^{1.42} N_{Fr}^{-0.21} N_P^{0.4} N_{Sc}^{0.5}$$

where ρ_g = density of gas (lb/ft^3)

$D_{i,air}$ = diffusion coefficient of i in air (ft^2/hr)

d = impellor diameter (ft)

Dimensionless numbers, N_{Re}, N_{Fr}, N_P, N_{Sc} are functions of a limited number of other factors:

ω = rotational speed (rad/sec)

μ_g = gas viscosity (g/cm - sec)

g = gravitational constant (32.17 ft/sec^2)

Pr = power to impellor (lb_f - ft/sec)

ρ_L = density of the liquid (lb/ft^3)

$N_{Re} = \rho_g d^2 \omega / \mu_g$ = Reynolds number

$N_{Fr} = d\omega^2/g$ = Froude number

$N_P = Pr\ g/\rho_L d^5 \omega^3$ = Power number

$N_{Sc} = \mu_g/\rho_g D_{i,air}$ = Schmidt number

Thus, $(k_G)_T$ becomes

$$(k_G)_T = 0.00039\ Pr^{0.4}\ \rho_L^{-.4}\ \rho_g^{1.92}\ D_{i,air}^{0.5}\ d^{-.4}\ \omega^{-.19}\ \mu_g^{0.92}\ g^{0.19}$$

Because both turbulent and non-turbulent surface conditions exist on an aerated impoundment, the overall mass transfer coefficient is a weighted average of the turbulent and non-turbulent (convective) coefficients. Thus, the overall transfer coefficient for a given component is estimated using area-weighted coefficients as follows:

$$K_L = (K_L)_C \frac{A_C}{A} + (K_L)_T \frac{A_T}{A}$$

where A_C = convective area of impoundment

A_T = turbulent area of impoundment

$A_C + A_T = A$ = total impoundment area

EXAMPLE CALCULATIONS
for
ESTIMATING EMISSIONS FROM SURFACE IMPOUNDMENTS
AT THE RENTON SEWAGE TREATMENT PLANT

The Renton Sewage Treatment Plant provides secondary treatment for approximately 50 MGD of influent. After initial separation of grit, influent enters the primary settling tanks for solids separation. To minimize turbulence the surface of the water in these tanks is below grade and the entire impoundment is surrounded and covered by wind breaking structures. After primary separation, the wastewater enters aeration tanks. Here, microorganisms and oxygen are added to consume organic contaminants. Aeration is by a submerged air bubble diffusion system. Flow control is versatile in secondary treatment allowing untreated and recycled waste water to be introduced at any of several locations along the treatment channel. Typically, treatment is conducted in two tank areas, each of which contains approximately 1,200 feet of channel.

Aerated wastewater moves to secondary sedimentation which is conducted in eight circular tanks each of which is 100 feet in diameter. Though the water surface is somewhat below tank wall level, there are no protective windbreaks. From these tanks, treated water enters the chlorine contact channel. This 933-foot long channel provides sufficient residence time for chlorination chemicals to disinfect the effluent prior to discharge to the Green River. Plant data necessary for estimating emissions are shown in Tables C-1 and C-2.

TABLE C-1

IMPOUNDMENT INFORMATION
Renton, WA Sewage Treatment Plant

IMPOUNDMENT NAME	AERATION?	SURFACE AREA (ft^2)
Primary Sedimentation	No	44,608
Secondary Aeration	Yes[1]	76,200
Secondary Sedimentation and Chlorination	No	74,027

[1] Aeration information:

The Renton Treatment Plant utilizes submerged air diffusers for aeration. For the purposes of emission calculation, this system is converted to an equivalent number of surface aerators (for which there are k estimators) based on equivalent O_2 transfer. The bubble diffuser system air is provided by four blowers each delivering 2900 cfm at 7.5 psi. The fine bubble diffuser system has a 12 percent oxygen transfer efficiency. This amount of oxygen is equivalent to that provided by eighteen 40-horsepower surface aerators.

Aerator data for 40 hp aerator:

Power transfer efficiency:	0.7
Turbulent area:	661 ft^2
Agitated volume:	8587 ft^3
Impellor diameter:	2 ft
Impellor speed:	1200 rpm

TABLE C-2

PHYSICAL DATA FOR SELECTED CHEMICALS
PRESENT IN
RENTON TREATMENT PLANT WASTEWATER

Chemical Species	Average Concentration[1] Influent (µg/l)	Effluent (µg/l)	Henry's Constant (atm-m^3/g-mole)	Molecular Weight (g/g-mole)
Diethylphthalate	8.94	4.16	4.75×10^{-5}	222
Methylene Chloride	37.1	45.3	3.19×10^{-3}	85
Phenol	67.6	46.7	1.3×10^{-6}	94
Trichloroethylene	22.2	11.7	8.92×10^{-3}	131
Tetrachloroethylene	20.0	14.7	2.87×10^{-2}	166

[1] Concentration data are from METRO's treatability evaluation (METRO, 1984b), which included an extensive sampling program. The METRO sampling program provides a better estimate of annual concentrations than could be achieved from samples taken at the Renton plant on July 11, 1985 as part of this study. Thus, the METRO values are superior for estimating annual emissions.

EMISSION ESTIMATES FOR RENTON
SEWAGE TREATMENT PLANT

Primary Clarification

This impoundment is not aerated so estimation of emissions is for convective surfaces only. Thus

$$k_L = (1.3\ Re^{*0.195} - 0.57)\ (MW_{benzene}/MWi)^{0.5}$$

and

$$k_G = U^{0.78}\ A^{-0.055}\ (.00325 - 5.54E\text{-}6\ MWi)$$

Using the previous data

Compounds	k_L[1]	k_G
Diethylphthalate	0.27	0.095
Methylene Chloride	0.27	0.130
Phenol	0.27	0.128
Trichloroethylene	0.27	0.118
Tetrachloroethylene	0.27	0.109

Since the H values for methylene chloride, trichloroethylene, and tetrachloroethylene all exceed 10^{-3}, $K_L = k_L = 0.27$

For phenol, H is less than 2×10^{-5} and $K_L = k_G = 0.128$

For diethylphthalate, K_L is given by

$$K_L = ((0.27)^{-1} + (55555(4.75E\text{-}5)\ 0.095)^{-1})$$

$$= 0.130$$

Emissions for the primary treatment process, based on mass transfer considerations, are estimated by:

$$Q = 18 \times 10^{-9}\ (K_L)\ C_{iL}\ A$$

$$= 8.03E\text{-}4\ K_L\ C_{iL}$$

Because emissions may be limited by the total mass of the component entering the primary clarifier, an estimate of the maximum potential emission (M) is prepared based on this entering mass.

---

[1] Based on a local wind speed of 2.5 m/sec

Compound	Primary Treatment Emissions (lb/hr)	
	Mass Transfer (Q)	Mass Entering (M)
Diethylphthalate	0.00093	0.15
Methylene Chloride	0.0080	0.64
Phenol	0.0069	1.17
Trichloroethylene	0.0048	0.38
Tetrachloroethylene	0.0043	0.35

These values are based on influent values only. As may be seen, emissions are not limited by mass entering primary treatment.

Secondary Treatment-Aerated

Emissions from convective areas of secondary treatment impoundments are calculated as above. Based on observation they are estimated to cover 10% of the aeration tank surfaces. Turbulent area emissions are estimated as follows:

Aeration due to the bubbler system is estimated to be equivalent to eighteen 40-hp aerators based on O_2 transfer rate. Thus,

$$(k_L)_T = \frac{3.0\ (40 \times .7)\ (1.024)^{15-20}\ 4850}{(0.0666)\ 8587} \left[\frac{D_{i,\ H_2O}}{D_{O_2,\ H_2O}}\right]^{0.5}$$

$$= 74732\ (D_{i,\ H_2O})^{0.5}$$

$$(k_G)_T = 0.00039\ Pr^{0.4}\ \rho_L^{-.4}\ \rho_g^{1.92}\ D_{i,atr}^{0.5}\ d^{-.4}\ \omega^{-.19}\ \mu_g^{0.92}\ g^{0.19}$$

where $Pr = 40\ hp \times 550 \frac{lb\text{-}ft}{sec\text{-}hp} = 22{,}000\ lb\text{-}ft/sec$

$\rho_L = 62.4\ lb/ft^3$

$\rho_g = 0.075\ MWi/28.9 = 0.0026\ MWi$

$d = 2.0\ ft$

$\omega = 1200\ rpm \times 2\ \pi/60 = 125.67^{rad}/sec$

$\mu_g = g/cm\text{-}sec$

$g = 32.17\ ft/sec^2$

Thus

$$(k_G)_T = 2.568E\text{-}8\ (MWi)^{1.92}\ D_{i,air}^{0.5}\ \mu_g^{0.92}$$

And individual mass transfer coefficients are estimated as follows:

Compound	$(k_L)_T$	$(k_G)_T$
Diethylphthalate	167	0.563
Methylene Chloride	268	
Phenol		0.133
Trichloroethylene	240	
Tetrachloroethylene	236	

Overall K value is then estimated by the following:

$$K_L = (K_L)_C \, A_C/A + (K_L)_T \, A_T/A$$

where $A_C/A = 0.1$

$A_T/A = 0.9$

Compound	$(K_L)_C$	$(K_L)_T$	K_L
Diethylphthalate	0.13	1.47	1.34
Methylene Chloride	0.27	268.	241.
Phenol	0.128	0.133	0.133
Trichloroethylene	0.27	240.	216.
Tetrachloroethylene	0.27	236.	212.

Emission estimate for aerated secondary treatment:

$$Q = 18 \times 10^{-9} \, K_L \, Ci_L A$$

$$= 1.371 \times 10^{-3} \, K_L \, Ci_L$$

or $Q = 7.62 \times 10^{-5} \, K_L \, Ci_L$ per aerator.

Flow through Renton Secondary treatment is split with each half being treated by the equivalent of nine 40 hp aerators in series. (In winter the influent may traverse as little as half this process.) Each successive equivalent aerator sees a lower pollutant concentration than the preceding one due to the loss of compound to the atmsophere. Based on a mass balance around each aerator, emissions decrease along the treatment channel. Thus, total emissions are based on the losses from nine successive aeration steps.

Compound	Secondary Treatment Emissions (lb/hr)	
	Mass Transfer (Q)	Mass Entering (M)
Diethylphthalate	0.016	0.15
Methylene Chloride	12.25	0.63
Phenol	0.012	1.16
Trichloroethylene	6.57	0.38
Tetrachloroethylene	5.81	0.35

Based on this analysis, the quantities of diethylphthalate and phenol are only partially depleted. Somewhat greater emissions might be expected based on sample data. The unaccounted for loss may be due to biological activity which is not addressed here. The other chemicals should be completely depleted though effluent measurements indicate this is not the case. It is believed the outfall measurements may be due to creation of chlorinated species in the chlorination channel or release of adsorbed materials that were not measured in influent and sludge analyses.

Secondary Clarification and Chlorine Contact Channel

Emissions from the secondary clarifier and chlorine contact channel are again limited by mass transfer from convective (non-aerated) surfaces. The appropriate concentration levels are not well known for volatile chlorinated compounds since there may be combined emissions and generation of these substances. Since emission rates are low under these circumstances, concentrations of these materials may increase along the length of the contact channel due to reactions between organic compounds and chlorine-based additives. The extent to which such reactions occur could not be documented as part of this study. However, to prepare a conservative estimate of emissions for these compounds, it was assumed a second in-plant peak in concentration occurred at the end of the contact channel. Thus, emission estimates were prepared using effluent concentrations for these materials.

Compound	Secondary Clarification and Chlorine Contact Emissions (lb/hr)
Diethylphthalate	0.0013
Methylene Chloride	0.0162
Phenol	0.0079
Trichloroethylene	0.0042
Tetrachloroethylene	0.0052

Total emissions for the Renton Sewage Treatment facility are shown in Table C-3. As may be noted the emission predictions for the compounds with low Henry's constant values, diethylphthalate and phenol, indicate that no more than one tenth of the entering material would be emitted. Substantial fractions would leave with the effluent which is consistent with measurement. It is estimated that the remainder is biologically degraded. The emission estimation equations would predict essentially 100 percent loss of volatiles to the air. Substantial loss is noted for volatiles except methylene chloride which actually shows an increase based on an analysis of mass entering and leaving the plant. Chlorine-based additives may react with organic compounds to cause this increase and account for relatively high levels of other chlorinated organics in the effluent.

TABLE C-3

ESTIMATED TOTAL EMISSIONS
RENTON SEWAGE TREATMENT PLANT
(lb/hr)

Compound	Mass Transfer				Mass Balance	
	Primary Treatment and Clarification	Secondary Treatment	Secondary Clarification & Chlorine Contact	Total	Mass Entering Only	Mass Entering Minus Mass Leaving
Diethylphthalate	0.0009	0.016	0.0013	0.015	0.150	0.085
Methylene Chloride	0.0080	0.630	0.0162	0.644	0.63	-0.146
Phenol	0.0064	0.012	0.0113	0.037	1.16	0.372
Trichloroethylene	0.0048	0.380	0.0042	0.385	0.38	0.187
Tetrachloroethylene	0.0043	0.350	0.0052	0.347	0.35	0.280

EXAMPLE CALCULATIONS FOR CEDAR HILLS LANDFILL EMISSIONS
using
Thibodeaux Landfill Equation with Internal Gas Generation (U.S. EPA, 1984a)

$$N_A = V_y \rho^*_{Ai} \left[\frac{1}{e^{(hV_y/D_{A3})^{-1}}} + 1 \right]$$

where: surface concentration assumed = 0 for all toxics

N_A = flux of component A in (gm/cm^2)

V_y = mean gas velocity in pore spaces (cm/sec)

ρ^*_{Ai} = conc. of component A in pore spaces (g/cc) (from landfill gas analysis)

h = cover depth (cm)

D_{A3} = effective diffusivity of component A in air-filled pore space (cm^2/sec)

D_{A3} is defined by:

$$D_{A3} = D_A \frac{\varepsilon}{\tau}$$

where: D_A = diffusivity of component A in air

ε = soil porosity; worst case $\varepsilon \doteq 0.62$

τ = tortuosity = 3

However, D_{A3} is considered to be better estimated for moist materials by correlations verified by Currie.

Based on empirical work by Currie:

$$\frac{D_{A3}}{D_A} = \Gamma(\varepsilon_T)^{\mu\sigma} (\varepsilon_a)^{\sigma}$$

where: $\sigma = 4$

$\mu = 1.4 - 11.0$)
> Empirically derived constants
$\Gamma = 0.8 - 1.0$)

ε_T = total porosity = $1 - \beta/\rho_p$ = 0.245 - 0.623

ε_a = wet soil porosity = $\varepsilon_T - \frac{\omega\beta}{\rho_{H_2O}}$ = 0.05 - 0.6

ω = soil moisture (g/g)

β = bulk density of soil (or waste) (g/cm^3) = 1.0 - 2.0 (0.5 - 0.7)

ρ_{H_2O} = water density = 1.0 g/cm^3

ρ_P = soil particle density = 2.65 (g/cm^3) (typical)
municipal waste density = 1.66 (g.cm) (typical)

Range for D_A : 0.089 - 0.173 cm^2/sec for volatile compounds

Estimation of pore gas velocity:

$$V_y = \frac{F_G}{\varepsilon_a} = \frac{\text{Gas flux}}{\text{wet soil porosity}}$$

$$V_y = \frac{\text{Mass of waste (tons)} \times P \ \frac{ft^3}{\text{lb-yr}} \times \text{unit correction factor}}{\varepsilon_a \times \text{landfill area (A)}}$$

P = gas production, typically, 0.15 ft^3/lb waste-yr

$$V_y = \frac{\text{Mass (tons)} \cdot P \cdot 4.438\ E\text{-}8}{\text{Area (A)}\ \varepsilon_a} \quad \text{(cm/sec)}$$

For Cedar Hills:*

$$V_y = \frac{8.7\ E\ 6\ \text{(tons)}\ 0.1003\ \frac{ft^3}{\text{lb-yr}}\ 4.438\ E\text{-}8}{34\ A\ \varepsilon_a}$$

$$= \frac{0.00113}{\varepsilon_a} \quad \text{cm/sec}$$

For Thibodeaux's equation;

assume whenever the diffusion term

$$\frac{1}{e^{(hV_y/D_{A3})^{-1}}} \leq 0.05$$

emissions are adequately estimated by the bio-gas flux term alone as it accounts for 95+% of emissions. For this to be true

$$\frac{hV_y}{D_{A3}} \geq 3.044$$

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* Average gas production rate for Cedar Hills is estimated at 0.1003 ft^3/lb-year based on studies specific to that site.

For covered areas of the landfill the following conditions were typical:

Temporary cover thickness = 15 in = 38.1 cm

Soil type: gravelly clay loam

$\mu = 1.7$

$\beta = 1.5$

$\rho = 2.65$

Moisture content = 5%

$\frac{D_{A3}}{D_A} = 0.106$ estimated worst case (Currie)

$\frac{D_{A3}}{D_A} = 0.141$ (Thibodeaux)

For this example analysis, assume the toxic of concern is formaldehyde

$D_A = 0.1729\ cm^2/sec$ and

$$\frac{hV_y}{D_{A3}} = \frac{38.1\ (0.0031\ cm/sec)}{.106\ (0.1729\ cm^2/sec)} = 6.54 \geq 3.044$$

Emissions are dominated by bio-gas flux.

For areas with no soil cover assume that a waste layer acts as a cover layer and that the effective cover of trash for which the diffusion component is responsible for 5% of total flux has thickness = h.

Waste data:

$\mu = 3.0$*
$\beta = 0.64$**
MC = 0.20***
$\rho = 1.66$**

* High percentage of paper in newer trash (60% by volume) assumed to give material a semi-platey nature. Value selected is between that of granular materials (μ= 1.4) and platey materials (μ= 11.0).

** Based on analysis of municipal waste Vancouver, WA (Mudge and Rohrmann, 1978).

*** Average of delivery MC of 5% and final MC of 30%

Using these values, the Currie correlation gives

$$D_{A3}/D_A = 0.091$$

For formaldehyde:

$$\frac{hV_y}{D_{A3}} = \frac{h\ (0.00232)}{(0.091)\ 0.1729} = 3.044$$

$$h = 20.6 \text{ cm}$$

Emissions in this layer will be due to both gas flux and diffusion. The simplest and most conservative assumption is to assume 100% loss of the toxic material in this layer from areas covered within the last year. This estimate requires a good understanding of the toxic makeup of entering waste.

Gross Emissions at Cedar Hills Due to Gas Flux

$$E = N_A \times \text{Area of flow}$$

$$= N_A \times \text{Landfill Area } (cm^2) \times \varepsilon_a$$

$$= \frac{\text{Mass} \cdot P \cdot 4.438E\text{-}8 \cdot \rho^*_{A1}}{\text{Area (A)} \cdot \varepsilon_a} \times \text{Area (A)} \times 40.46E6\ (cm^2/A) \times \varepsilon_a$$

$$= \text{Mass (ton)} \cdot P \left(\frac{ft^3}{lb\text{-}yr}\right) \cdot \rho^*_{A1} \left(g/cm^3\right) \times 1.795$$

For concentrations in mg/m^3 and emissions in lbs:

$$E(lb/yr) = 1.247\ E\text{-}4 \times (\text{mass of waste in ton}) \times \left(\text{gas production rate in } \frac{ft^3}{lb\text{-}yr}\right) \times (\text{Toxic component conc. in } mg/m^3)$$

Of this total toxic component emission, a fraction is released through flares. The flare combustion is assumed to be 90% efficient, thus actual emissions are:

$$\text{Net emissions for component A} = E_T - E_F + E_F\ (0.10)$$

$$= E_T - 0.9E_F$$

or

$$\frac{\text{Net emissions}}{\text{Gross emissions}} = 1 - 0.9\,\frac{E_F}{E_T}$$

$$= 1 - 0.9\,\frac{N_F \times V_F}{V_T}$$

where N_F = number of effective flares

V_F = volume of gas per flare

V_T = total volume of gas for landfill

At Cedar Hills the number of effective flares is estimated at 15. Based on measured flow of 30 cfm at other landfills:

$$\frac{\text{Net emissions}}{\text{Gross emissions}} = 1 - (0.9)\,\frac{15 \times 15.7\ E6}{1679E6}$$

$$= 0.87$$

Emissions for toluene for example would then be estimated by:

$$E_{tol} = 1.24E\text{-}4 \times 8.7\ E6\ \text{tons} \times 0.1003\ \frac{ft^3}{lb\text{-}yr} \times 133.11\ \frac{mg}{m^3} \times 0.87$$

$$= 12601\ \text{lb/yr} = 6.30\ \text{ton/year}$$

LANDFILL EMISSIONS
WITHOUT BIOGAS GENERATION

Emissions from buried materials occur by diffusion through the covering layer. Emissions for compound i are estimated by:

$$E = k_{soil}\, C_{ig}\, A$$

where: E = emission rate in grams/sec

k_{soil} = soil phase diffusion parameter

C_{ig} = vapor concentration of compound i in the soil or waste

A = surface area of landfill (cm^2)

Diffusion through the boundary air layer is not considered because soil resistance to diffusion dominates the overall resistance to mass transfer. The Currie correlation for k_{soil} is selected since it addresses wet soil conditions typical of the area investigated here. The Currie correlation is given by:

$$k_{soil} = \frac{(D_{i,air})\, \Gamma(\varepsilon_t)^{\mu\sigma}\, (\varepsilon_a)^{\sigma}}{h}$$

with variables defined as in the Cedar Hills example.

The vapor concentration may be calculated by the following equation:

$$C_{ig} = \frac{W_i\, a_i\, P_i\, MW}{RT}$$

where: W_i = weight percent of the compound in the soil

a_i = activity coefficient of i

P_i = vapor pressure of i (mmHg)

MW = average molecular weight of waste (g/g-mol)

R = universal gas constant (624.0 mmHg-cm^3/gmol-k)

T = temperature (°K)

EXAMPLE CALCULATION
EMISSIONS FROM WESTERN PROCESSING
SUPERFUND SITE

The Western Processing site consists of four sub-areas, the soils of which are contaminated with a variety of organic species. Based on information in the Feasibility Study for Subsurface Cleanup (USEPA, 1985a), four areas and their contamination levels are summarized in the attached Tables C-4 through C-6.

Because removal of contaminated soil is proposed over much of the site, two emission scenarios are calculated: before and during excavation. In each case, the mixture of compounds are represented by the most volatile species of those identified by EPA. This approach coupled with worst case concentration assumption should provide a conservative emission estimate. Contaminant and soil data are shown in the attached tables.

Excavation volumes and weighted concentrations are developed for remedial action proposal V of the reference. These values are shown in Table C-4 along with depth information for contaminant deposits. The weighted soil concentration values for each designated area allow soil pore vapor concentrations, C_{ig} to be estimated. k_{soil} values are calculated using the listed soil data and assuming a mean depth. These are shown in Table C-7.

Utilizing the calculated soil pore vapor concentrations, affected areas, and k_{soil}, emission estimates are prepared for the undisturbed site. These are shown in Table C-8.

During excavation contaminated soil will be exposed each day. Emissions from freshly exposed soil will be relatively rapid until the concentrations in exposed layer decrease. At this time the layer serves to restrict the diffusion and emission of additional contaminants. Rather than attempting to estimate these emissions using a time dependent model, a simplification for calculational purposes was adopted.

TABLE C-4

WESTERN PROCESSING SITE DATA (USEPA, 1985a)

Area	Excavation Data				Contaminant Data			
					Weight Concentration (ppb)			
	Area (ft^2)	Depth (ft)	Volume (cu.yd.)	Face Area (ft^2)	Vol.	Acid Extract.	PAHs	Phthalates
I & II	5.54E5	15	3.08E5	6,500	8,090	3,100	167,550	128,900
V	1.26E5	3	1.4E 4	540	100	1,450	150	620
VIII	9.0E4	3	1.0E 4	450	200	0	34,500	250
IX	4.5E4	1	1.6E 3	180	20	0	0	2,000
Depth below surface where compounds most frequently found (ft)					6-9	9-21	0-3	0-9

TABLE C-5

WESTERN PROCESSING SOIL CONTAMINANT DATA

Compound Group	Representative Compound	Vapor Pressure (mmHg)	Molecular Weight (g/g-mol)	Diffusivity in Air (cm^2/sec)
Volatiles	1,1,1-Trichloroethane	117	133	0.0794
Acid Extractables	Cumene	4.507	120	0.0702
PAHs	Naphthalene	0.232	128	0.0668
Phthalates	Diethylphthalate	8.1E-3	222	0.0513

Average MW of waste = 140 g/g-mol

TABLE C-6

WESTERN PROCESSING SITE SOIL DATA

Soil Type: Sandy Clay Loam

Bulk density, β: 1.26 g/cm^3

Porosity, ε_T: 0.50

Moisture Content: 20 percent*

and

Γ = 0.9

μ = 2.0

σ = 4

ε_a = 0.25

* Assumes water table lowered as for excavation as proposed (USEPA, 1985a)

TABLE C-7

SOIL PORE VAPOR CONTAMINANTS CONCENTRATIONS (g/cm^3)

Area Designation	Area (cm^2)	1,1,1-Trichloroethane	Cumene	Naphthalene	Diethylphthalate
I & II	5.15E8	6.77E-8	9.0E-10	2.67E-9	1.25E-10
V	1.17E8	8.37E-10	4.2E-10	2.39E-12	6.00E-13
VIII	8.36E7	1.67E-9	0	5.51E-10	2.42E-13
IX	4.1E7	1.67E-10	0	0	1.93E-12
k_{soil} (cm/sec)		4.9E-6	3.6E-6	2.1E-5	5.3E-6

TABLE C-8

UNDISTURBED SITE EMISSIONS

Compound Group	Emissions	
	g/sec	T/Y
Volatiles	1.72E-4	5.97E-3
Acid Extractables	1.85E-6	6.43E-5
PAHs	2.98E-5	1.04E-3
Phthalate	3.42E-7	1.19E-5
		7.09E-3

Complete volatilization of toxic materials in a newly exposed soil layer was assumed within the first day with emissions from the remaining buried waste then restricted by this layer. The thickness of this layer was determined by equating the loss by evaporation of all of the compound in the layer to the loss through the layer by diffusion. Thus layer thickness increases as volatility increase. This method over-predicts consistently by a factor of less than two and avoids the need to evaluate daily emissions using time-dependent models and the errors resulting from an assumed constant thickness.

Thus, on a daily basis:

$$E_{diffusion} = E_{evaporation}$$

or $$86{,}400\ k_{soil}\ C_{ig}\ A_f = \beta W_i\ t\ A_f$$

where A_f = area of the excavated face (each day)

t = layer thickness

and k_{soil} is based on t rather than the depth of the waste below the surface. This equation is solved for t which is then used to estimate emissions. Thus t is given by:

$$t = 86{,}400 \left(\frac{D_{i,air}\ (\text{Currie correlation})\ C_{ig}}{W_i \beta} \right)^{0.5}$$

or

$$t = 86{,}400 \left(\frac{D_{i,air}\ (\text{Currie correlation})\ a_i\ P_i\ MW}{\beta RT} \right)^{0.5}$$

Daily emissions are estimated as:

$$E \leq 2\ A_f\ t\ W_i\ \beta$$

Assuming a broad excavation face, 6500 square feet are exposed on each of 410 days expected to be required to complete removal of Areas I and II. Emissions of compound i are estimated by:

$$E \leq 1.21E7\ W_i\ \beta\ t \quad \text{(Areas I \& II)}$$

Estimated daily emissions are shown in the attached Table C-9 for designated excavation areas.

TABLE C-9

DAILY SITE EMISSIONS DURING EXCAVATION
(gm/day)

Area Designation	A_f (ft^2)	Excavation Duration (days)	Contaminants			
			1,1,1-Trichloroethane	Cumene	Naphthalene	Diethylphthalate
I & II	6,500	410	100.1	7.02	86.0	10.70
V	540	19	0.1	0.27	6.4E-3	4.3E-3
VIII	450	13	0.17	0	1.22	1.4E-3
IX	180	2	6.8E-3	0	0	4.6E-3
Layer Thickness, t(cm)			0.82	0.15	0.034	0.0055

EMISSION CALCULATIONS FOR SOLVENT RECOVERY OPERATIONS - CHEMICAL PROCESSORS, INC.

Emission factors for solvent recovery operations are taken from "Supplemental Report on the Technological Assessment of Treatment Alternatives for Waste Solvents" (Engineering-Science, 1985). These factors are based on a survey of state agencies described in the referenced report. The factors are listed in the attached Table C-10. It is believed that these factors are directly applicable to both the Chem-Pro and Lilyblad facilities. However, they would tend to over-predict Chem-Pro emissions slightly due to that company's use of underground storage for finished product.

For each operation, throughput of solvent is multiplied by the emission factor to obtain a point emission estimate.

TABLE C-10

EMISSION FACTORS FOR SOLVENT RECLAIMING[a]
(Engineering-Science, 1985)

Source	Criteria Pollutant	Emission Factor Average	
		lb/ton	kg/MT
Storage Tank Vent[b]	Volatile Organics	0.02 (0.004-0.09)	0.01 (0.002-0.04)
Condenser Vent	Volatile Organics	3.30 (0.52-8.34)	1.65 (0.26-4.17)
Incinerator Stack[c]	Volatile Organics	0.02	0.01
Incinerator Stack	Particulates	1.44 (1.1-2.0)	0.72 (0.55-1.0)
Fugitive Emissions			
Spillage[c]	Volatile Organics	0.20	0.10
Loading	Volatile Organics	0.72 (0.00024-1.42)	0.36 (0.00012-0.71)
Leaks	Volatile Organics	NA	NA
Open Sources	Volatile Organics	NA	NA

a Data obtained from state air pollution control agencies and presurvey sampling. All emission factor are for uncontrolled process equipment, except those for the incinerator stack. (Reference 1 does not, however specify what the control is on the stack.) Average factors are derived from the range of data points available. Factors for these sources are given in terms of pounds per ton and kilograms per metric ton of reclaimed solvent. Ranges in parentheses.

b Storage tank is of fixed roof design.

c Only one value available.

NA - Not available

EXAMPLE CALCULATION FOR CHEMICAL PROCESSORS, INC.

Drum storage data contained in the Hazardous Waste Facility Data for 1983 (WDOE, 1985) is summarized into categories shown in Table C-11. Weighting the solvent waste storage data by estimated solvent content gives a value of 118.1 tons of solvent through drum storage. Solvent emissions from drum storage are estimated by 0.00125 lb. solvent/ton-yr.

Waste processed by distillation (treatment code T63) also was quantified from the WDOE report and is summarized in Table C-12.

Based on typical 95% recovery noted by Chem-Pro, solvent throughput and emissions are shown in Table C-13.

Review of RCRA data indicate approximately 38% of the solvents handled by Chem-Pro are typically classified as air toxics. Thus, the air toxic emission is estimated as 1.09 tons per year.

TABLE C-11

DRUM STORAGE QUANTITIES FOR CHEMICAL PROCESSORS
(Tons/Year)

Waste Code	Aqueous	Liquid	Liquid and Solid	Sludge
Assumed % Solvent	5	90	25	10
D001		61.6	62.8	7.2
F001		0.4	1.4	
F002		4.2	3.7	
F003				6.3
U211		0.4		
U220		0.2		
WP01	9.6	12.2		
WP02	20.6	0.9		
WT01	19.0	27.2		
Totals	49.2	107.1	67.9	23.5

TABLE C-12

DISTILLATION TREATMENT QUANTITIES

Waste Code	Quantity Treated (ton/yr)
D001	256.02
F001	158.21
F002	19.08
F003	328.29
F005	58.70
WP02	1.25
WT02	50.51
	872.05

TABLE C-13

EMISSION ESTIMATES FOR SOLVENT RECOVERY FACILITIES

	Chem-Pro	
	Solvent Throughput (T/Y)	Estimated Emissions (T/Y)
Drum Storage	118.1	0.15
Tank Filling & Storage (Receiving)	840.0	0.31
Drum Decant	6.8	0.34
Distillation	840.0	1.44
Process Fugitives	840.0	0.03
Still Bottom Disposal	10.0	0.01
Product Solvent Storage	830.0	0.31
Truck & Drum Filling	830.0	0.30
		2.89

APPENDIX D

Results of Sample Analysis

KEY FOR FACILITY CODES

CC - Chambers Creek Sewage Treatment Plant

ESTP - Everett Sewage Treatment Plant

WEY - Weyerhaeuser (Everett)

S - Scott Paper Company (Everett)

WYC - Wyckoff

REN - Renton Sewage Treatment Plant

CHCF = CHLF - Cedar Hills Landfill

ENGINEERING-SCIENCE

Priority Pollutant Analysis
Volatile Organics - EPA 624

Date Received:
Date Reported: 10/9/85

Job No.: 8037.28

For: ES - Boise

Attn: Scott Freeburn

Address: 348 Winged Foot Place, Eagle, ID 83616

Lab No:	851572	851575	851576	851580
Source of Sample:	CC001	CC004	ESTP001	ESTP005
Date Collected:	7/8/85	7/8/85	7/9/95	7/9/85
Time Collected:	1130	1130	--	--
Type of Sample:	Water	Water	Water	Water

Compound	Detection Limit mg/L	ANALYTICAL RESULTS mg/L	mg/L	mg/L	mg/L
Chloromethane	0.05	nd	nd	nd	nd
Bromomethane	0.05	nd	nd	nd	nd
Vinyl Chloride	0.05	nd	nd	nd	nd
Chloroethane	0.05	nd	nd	nd	nd
Dichloromethane	0.05	nd	0.2	nd	nd
Trichlorofluoromethane	0.05	nd	nd	nd	nd
1,1-Dichloroethene	0.05	nd	nd	nd	nd
1,1-Dichloroethane	0.05	nd	nd	nd	nd
trans-1,2-Dichloroethene	0.05	nd	nd	nd	nd
Chloroform	0.05	nd	nd	nd	nd
cis-1,2-Dichloroethene	0.05	nd	nd	nd	nd
1,2-Dichloroethane	0.05	nd	nd	nd	nd
1,1,1-Trichloroethane	0.05	nd	nd	nd	nd
Carbon Tetrachloride	0.05	nd	nd	nd	nd
Bromodichloromethane	0.05	nd	nd	nd	nd
1,2-Dichloropropane	0.05	nd	nd	nd	nd
1,2-Dibromoethane	0.05	nd	nd	nd	nd
trans-1,3-Dichloropropene	0.05	nd	nd	nd	nd
Trichloroethene	0.05	nd	nd	nd	nd
Benzene	0.05	nd	nd	nd	nd
Dibromochloromethane	0.05	nd	nd	nd	nd
1,1,2-Trichloroethane	0.05	nd	nd	nd	nd
cis-1,3-Dichloropropene	0.05	nd	nd	nd	nd
2-Chloroethyl vinyl ether	0.05	nd	nd	nd	nd
Bromoform	0.05	nd	nd	nd	nd
1,1,2,2-Tetrachloroethane	0.05	nd	nd	nd	nd
Tetrachloroethene	0.05	nd	nd	nd	nd

Lab No:	851572	851575	851576	851580
Source of Sample:	CC001	CC004	ESTP001	ESTP005
Date Collected:	7/8/85	7/8/85	7/9/95	7/9/85
Time Collected:	1130	1130	--	--
Type of Sample:	Water	Water	Water	Water

Compound	Detection Limit mg/L	ANALYTICAL RESULTS mg/L	mg/L	mg/L	mg/L
Toluene	0.05	nd	nd	0.2	nd
Chlorobenzene	0.05	nd	nd	nd	nd
Ethylbenzene	0.05	nd	nd	nd	nd
1,2-Dichlorobenzene	0.05	nd	nd	nd	nd
1,3- & 1,4-Dichlorobenzene	0.05	nd	nd	nd	nd
Total xylenes	0.05	nd	nd	nd	nd
Styrene	0.05	nd	nd	nd	nd

ENGINEERING-SCIENCE
Priority Pollutant Analysis
Volatile Organics - EPA 624

Date Received: 7/11/85
Date Reported: 10/9/85

Job No.: 8037.28

For: ES - Boise

Attn: Scott Freeburn

Address: 348 Winged Foot Place, Eagle, ID 83616

Lab No:	851582	851586	851588	851592
Source of Sample:	WEY001	WEY004	S001	S007
Date Collected:	7/9/85	7/9/85	7/9/95	7/9/85
Time Collected:	--	--	--	--
Type of Sample:	Water	Water	Water	Water

Compound	Detection Limit mg/L	ANALYTICAL RESULTS mg/L	mg/L	mg/L	mg/L
Chloromethane	0.05	nd	nd	nd	nd
Bromomethane	0.05	nd	nd	nd	nd
Vinyl Chloride	0.05	nd	nd	nd	nd
Chloroethane	0.05	nd	nd	nd	nd
Dichloromethane	0.05	nd	nd	nd	nd
Trichlorofluoromethane	0.05	nd	nd	nd	nd
1,1-Dichloroethene	0.05	nd	nd	nd	nd
1,1-Dichloroethane	0.05	nd	nd	nd	nd
trans-1,2-Dichloroethene	0.05	nd	nd	nd	nd
Chloroform	0.05	13	0.06	0.8	nd
cis-1,2-Dichloroethene	0.05	nd	nd	nd	nd
1,2-Dichloroethane	0.05	nd	nd	nd	nd
1,1,1-Trichloroethane	0.05	nd	nd	nd	nd
Carbon Tetrachloride	0.05	nd	nd	nd	nd
Bromodichloromethane	0.05	nd	nd	nd	nd
1,2-Dichloropropane	0.05	nd	nd	nd	nd
1,2-Dibromoethane	0.05	nd	nd	nd	nd
trans-1,3-Dichloropropene	0.05	nd	nd	nd	nd
Trichloroethene	0.05	nd	nd	nd	nd
Benzene	0.05	nd	nd	nd	nd
Dibromochloromethane	0.05	nd	nd	nd	nd
1,1,2-Trichloroethane	0.05	nd	nd	nd	nd
cis-1,3-Dichloropropene	0.05	nd	nd	nd	nd
2-Chloroethyl vinyl ether	0.05	nd	nd	nd	nd
Bromoform	0.05	nd	nd	nd	nd
1,1,2,2-Tetrachloroethane	0.05	nd	nd	nd	nd
Tetrachloroethene	0.05	nd	nd	nd	nd

Lab No:	851582	851586	851588	851592
Source of Sample:	WEY001	WEY004	S001	S007
Date Collected:	7/9/85	7/9/85	7/9/95	7/9/85
Time Collected:	--	--	--	--
Type of Sample:	Water	Water	Water	Water

Compound	Detection Limit mg/L	ANALYTICAL RESULTS mg/L	mg/L	mg/L	mg/L
Toluene	0.05	nd	nd	nd	0.2
Chlorobenzene	0.05	nd	nd	nd	nd
Ethylbenzene	0.05	nd	nd	nd	nd
1,2-Dichlorobenzene	0.05	nd	nd	nd	nd
1,3- & 1,4-Dichlorobenzene	0.05	nd	nd	nd	nd
Total xylenes	0.05	nd	nd	nd	nd
Styrene	0.05	nd	nd	nd	nd

ENGINEERING-SCIENCE
Priority Pollutant Analysis
Volatile Organics - EPA 624

Date Received: 7/16/85
Date Reported: 10/9/85

Job No.: 8037.28

For: ES - Boise

Attn: Scott Freeburn

Address: 348 Winged Foot Place, Eagle, ID 83616

Lab No:	851698	851701	851719	851723
Source of Sample:	WYC004	WYC009	REN001	REN005
Date Collected:	--	--	7/11/95	7/11/85
Time Collected:	--	--	--	--
Type of Sample:	Water	Water	Water	Water

Compound	Detection Limit mg/L	ANALYTICAL RESULTS mg/L	mg/L	mg/L	mg/L
Chloromethane	0.05	nd	nd	nd	nd
Bromomethane	0.05	nd	nd	nd	nd
Vinyl Chloride	0.05	nd	nd	nd	nd
Chloroethane	0.05	nd	nd	nd	nd
Dichloromethane	0.05	nd	nd	nd	nd
Trichlorofluoromethane	0.05	nd	nd	nd	nd
1,1-Dichloroethene	0.05	nd	nd	nd	nd
1,1-Dichloroethane	0.05	nd	nd	nd	nd
trans-1,2-Dichloroethene	0.05	nd	nd	nd	nd
Chloroform	0.05	nd	nd	nd	nd
cis-1,2-Dichloroethene	0.05	nd	nd	nd	nd
1,2-Dichloroethane	0.05	nd	nd	nd	nd
1,1,1-Trichloroethane	0.05	nd	nd	nd	nd
Carbon Tetrachloride	0.05	nd	nd	nd	nd
Bromodichloromethane	0.05	nd	nd	nd	nd
1,2-Dichloropropane	0.05	nd	nd	nd	nd
1,2-Dibromoethane	0.05	nd	nd	nd	0.1
trans-1,3-Dichloropropene	0.05	nd	nd	nd	nd
Trichloroethene	0.05	nd	nd	nd	nd
Benzene	0.05	nd	nd	nd	nd
Dibromochloromethane	0.05	nd	nd	nd	nd
1,1,2-Trichloroethane	0.05	nd	nd	nd	nd
cis-1,3-Dichloropropene	0.05	nd	nd	nd	nd
2-Chloroethyl vinyl ether	0.05	nd	nd	nd	nd
Bromoform	0.05	nd	nd	nd	nd
1,1,2,2-Tetrachloroethane	0.05	nd	nd	nd	nd
Tetrachloroethene	0.05	nd	nd	nd	nd

Lab No:	851698	851701	851719	851723
Source of Sample:	WYC004	WYC009	REN001	REN005
Date Collected:	--	--	7/11/95	7/11/85
Time Collected:	--	--	--	--
Type of Sample:	Water	Water	Water	Water

Compound	Detection Limit mg/L	ANALYTICAL RESULTS mg/L	mg/L	mg/L	mg/L
Toluene	0.05	nd	nd	nd	nd
Chlorobenzene	0.05	nd	nd	nd	nd
Ethylbenzene	0.05	0.1	nd	nd	nd
1,2-Dichlorobenzene	0.05	nd	nd	nd	nd
1,3- & 1,4-Dichlorobenzene	0.05	nd	nd	nd	nd
Total xylenes	0.05	0.2	nd	nd	nd
Styrene	0.05	0.8	nd	nd	nd

ENGINEERING-SCIENCE
Priority Pollutant Analysis
Volatile Organics - EPA 624

Date Received: 7/16/85
Date Reported: 10/9/85

Job No.: 8037.28

For: ES - Boise

Attn: Scott Freeburn

Address: 348 Winged Foot Place, Eagle, ID 83616

Lab No:	851707	851710	851711	851712
Source of Sample:	CHCF001	CHCF004	CHCF005	CHCF006
Date Collected:	7/12/85	7/12/85	7/12/95	7/12/85
Time Collected:	--	--	--	--
Type of Sample:	Charcoal tube	Charcoal tube	Charcoal tube	Charcoal tube

Compound	Detection Limit ug/sample	ANALYTICAL RESULTS ug/sample	ug/sample	ug/sample	ug/sample
Chloromethane	2	nd	nd	nd	nd
Bromomethane	2	nd	nd	nd	nd
Vinyl Chloride	2	nd	nd	nd	nd
Chloroethane	2	nd	nd	nd	nd
Dichloromethane	2	nd	nd	nd	nd
Trichlorofluoromethane	2	nd	nd	nd	nd
1,1-Dichloroethene	2	nd	nd	nd	nd
1,1-Dichloroethane	2	nd	nd	nd	nd
trans-1,2-Dichloroethene	2	nd	nd	nd	nd
Chloroform	2	nd	nd	nd	nd
cis-1,2-Dichloroethene	2	nd	nd	nd	nd
1,2-Dichloroethane	2	nd	nd	nd	nd
1,1,1-Trichloroethane	2	nd	nd	nd	nd
Carbon Tetrachloride	2	nd	nd	nd	nd
Bromodichloromethane	2	nd	nd	nd	nd
1,2-Dichloropropane	2	nd	nd	nd	nd
1,2-Dibromoethane	2	nd	nd	nd	nd
trans-1,3-Dichloropropene	2	nd	nd	nd	nd
Trichloroethene	2	nd	nd	nd	nd
Benzene	2	nd	nd	nd	nd
Dibromochloromethane	2	nd	nd	nd	nd
1,1,2-Trichloroethane	2	nd	nd	nd	nd
cis-1,3-Dichloropropene	2	nd	nd	nd	nd
2-Chloroethyl vinyl ether	2	nd	nd	nd	nd
Bromoform	2	nd	nd	nd	nd
1,1,2,2-Tetrachloroethane	2	nd	nd	nd	nd
Tetrachloroethene	2	nd	nd	nd	nd

Lab No:	851707	851710	851711	851712
Source of Sample:	CHCF001	CHCF004	CHCF005	CHCF006
Date Collected:	7/12/85	7/12/85	7/12/95	7/12/85
Time Collected:	--	--	--	--
Type of Sample:	Charcoal tube	Charcoal tube	Charcoal tube	Charcoal tube

Compound	Detection Limit ug/sample	ANALYTICAL RESULTS ug/sample	ug/sample	ug/sample	ug/sample
Toluene	2	11	500	nd	nd
Chlorobenzene	2	nd	nd	nd	nd
Ethylbenzene	2	nd	nd	nd	nd
1,2-Dichlorobenzene	2	nd	nd	nd	nd
1,3- & 1,4-Dichlorobenzene	2	nd	nd	nd	nd
Total xylenes	2	53	2400	nd	nd
Styrene	2	nd	620	nd	nd

LANDFILL GAS TOXIC COMPONENT CONCENTRATIONS

CEDAR HILLS LANDFILL

Well ID No.	Sample No.*	Sample Flow Rate (l/m)	Sampling Period (min.)
SW-2	CHLF-001	0.146	3.0
	CHLF-002	"	"
	CHLF-003	"	"
SW-3	CHLF-004	"	"
	CHLF-005	"	"
	CHLF-006	"	"

Well ID No.	Concentrations of Toxic Compounds (ug/l)		
	Toluene	Xylenes(all)	Styrene
SW-2	75.3	363.	ND
SW-3	3420.	16,400.	4250.

* Samples CHLF-002,-003,-005,-006 were back-up tubes. All sample was collected on tubes CHLF-001 and CHLF-004.