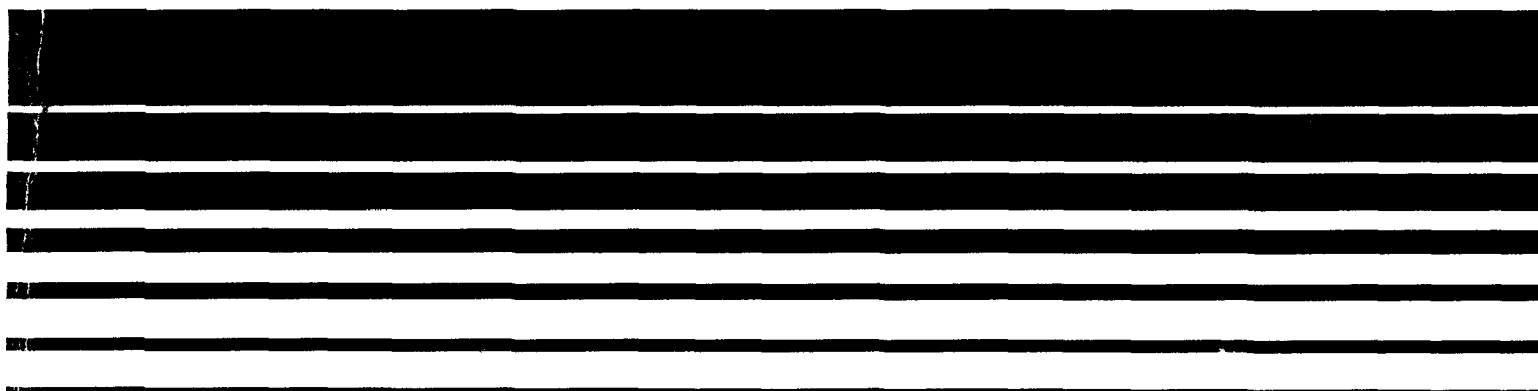




AIR/SUPERFUND NATIONAL TECHNICAL GUIDANCE STUDY SERIES

ESTIMATION OF AIR IMPACTS FOR SOLIDIFICATION AND STABILIZATION PROCESSES USED AT SUPERFUND SITES



**ESTIMATION OF AIR IMPACTS
FOR SOLIDIFICATION AND STABILIZATION
PROCESSES USED AT SUPERFUND SITES**

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INTRODUCTION

The U.S. Environmental Protection Agency's Office of Air Quality Planning and Standards and the Regional Air Offices have been given the responsibility to evaluate air impacts from Superfund sites. An important part of this program is the analysis of air impacts from various alternatives for cleaning up Superfund sites. Since these analyses are frequently required for planning purposes prior to actual cleanup, they depend on estimated emissions and ambient concentrations rather than on field measurements.

This report provides procedures for roughly estimating the ambient air concentrations associated with the solidification/stabilization of contaminated soil or sludge. These procedures are analogous to procedures for air strippers, soil vapor extraction systems, and excavation that have previously been published^{1,2,3}. Solidification/stabilization processes are used to immobilize toxic and hazardous constituents in contaminated soil or sludge. Procedures are given to evaluate the effect of treatment rate and contaminant concentration on the emission rates and on the ambient air concentrations at selected distances from the treatment area.

Health-based ambient air action levels are also provided for comparison to the estimated ambient concentrations. Many of the health levels have not been verified by EPA or are based on extrapolations of oral exposures or occupational exposures. Their use could either under or over estimate the potential health effects. The use of action levels that are neither EPA-verified nor EPA-approved should be considered on a case-by-case basis. The statements and conclusions presented in this report are those of the authors and do not reflect U.S. EPA policy.

PROCESS DESCRIPTION

Information related to air emissions from solidification/stabilization (S/S) processes is very limited. The following discussion is adapted from a recent compilation

models⁴. Additional general information about S/S processes is contained in Cullinane, et.al.⁵.

Stabilization and solidification technologies are gaining increased use as Superfund site remediation methods. The goal of these processes is to immobilize the toxic and hazardous constituents in the waste, usually contaminated soil or sludge. This can be accomplished by several means:

- 1) Changing the constituents into an immobile (insoluble) form;
- 2) Binding them in an immobile, insoluble matrix; or
- 3) Binding them in a matrix which minimizes the material surface exposed to solvents (groundwater) which could leach the hazardous constituents.

A few S/S processes involve in-situ treatment, however, most generally require excavation and other soil handling activities. Nearly all the commercially available stabilization and solidification technologies are proprietary. S/S processes may be considered to be point sources of VOC emissions if the process is enclosed or has an air collection system.

Solidification and stabilization processes are usually batch operations, but may be continuous. All ex-situ S/S processes follow the same basic steps shown in Figure 1. Wastes are first loaded into the mix bin (wastes are sometimes dried before addition to the bin), and other materials for the solidification or stabilization are added. The contents of the bin are then thoroughly mixed. After a sufficient residence time, the treated waste is removed from the bin. The amount of fixative added may be equal to the mass of the contaminated material. The solidified material is usually formed into blocks and allowed to cure for up to several days. The blocks can then be placed in lined excavations on-site. This description does not apply, however, to in-situ treatment methods, which use a variety of techniques (from applied high voltage to injection of stabilizing agents) to immobilize the contaminated waste in-place without excavation or soils handling.

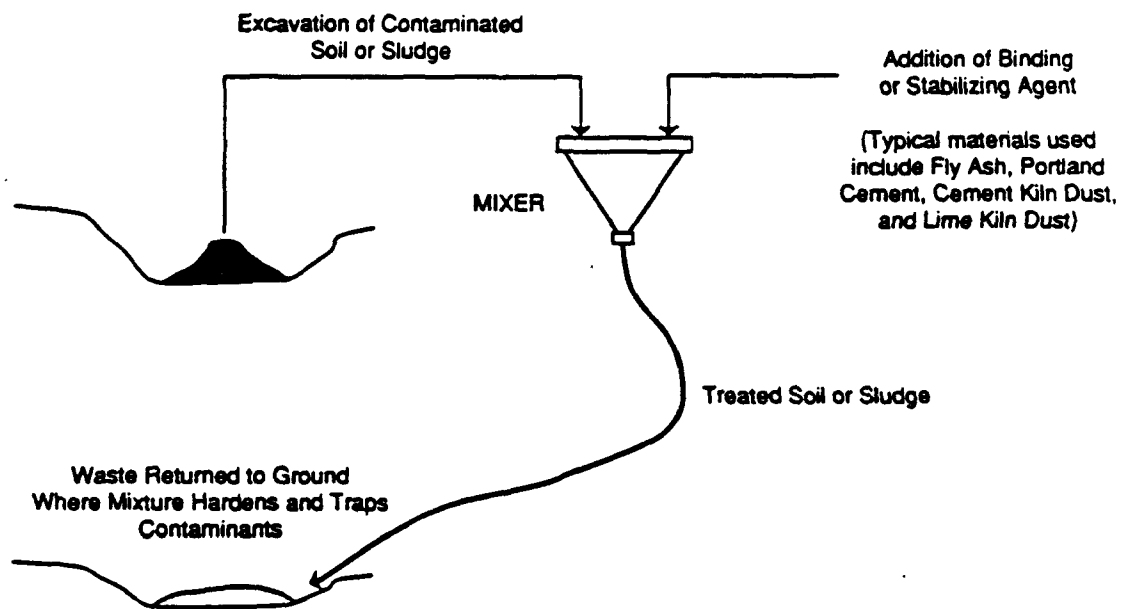


Figure 1. Process Flow Diagram for Ex-Situ Stabilization and Solidification

Typical raw materials used in stabilization processes include fly ash, portland cement, cement kiln dust, lime kiln dust, or hydrated lime. Other additives that may be used to solidify or encapsulate wastes include asphalt, paraffin, polyethylene, or polypropylene.

During the solidification/stabilization soil remediation process, there are numerous possible VOC and PM emission sources, including fugitive emissions before treatment, emissions during excavation and soil handling, during the preparation of the mixing agent, during the treatment of the contaminated soil, and, finally, emissions from the treated soil after remediation.

The primary source of VOC emissions from stabilization and solidification processes is volatilization of organic contaminants in the material to be treated. Volatilization can occur during waste handling activities such as soil excavation and transport or during the process of mixing the binding agents with the waste. Also, some evaporative emissions will occur from waste even after stabilization, especially during the curing period immediately after the blocks are formed. Lab studies, though, have shown that the largest fraction of volatile loss occurs during the mixing phase because heat may be required to assist mixing or may be generated by exothermic stabilization reactions.

In general, VOC emissions from stabilization and solidification processes will depend on the type and concentration of the VOCs in the waste, the duration and thoroughness of the mixing, the amount of heat generated in the process, and the average batch size processed. The longer or more energetic the mixing and processing, the greater likelihood that organic compounds will volatilize. The volatile losses will also increase as the temperature of the waste/binder mixture increases. Binding agents with high lime contents generally cause highly exothermic reactions. The batch size influences volatilization by affecting the mean distance a volatilized molecule has to travel to reach the air/solid interface at the surface of the stabilized waste. The larger the block of material, the lower the rate of volatilization.

Factors influencing the (uncontrolled) VOC emission rate also include the soil permeability before and after remediation, the exact treatment process and how the mixing is accomplished, and the composition of the mixing agent. Indeed, the latter may be specifically designed to control one certain class of contaminants, and may not be effective for any others. The impermeability of the treated soil will also determine the amount of emissions (and leachate) that escape.

Emissions of particulate matter (PM) from S/S processes also can be significant. The PM emission potential will depend on the moisture content and particle size distribution of the material to be treated. Process design and operating factors such as the duration and thoroughness of the mixing and the degree to which the process is enclosed also will affect the PM emission rate. Additional PM emissions may result from material handling operations associated with the stabilization agent or other raw materials (e.g., fly ash, kiln dust).

ESTIMATION OF VOC AIR EMISSIONS

Little information exists about the fate of volatile contaminants in wastes treated by stabilization and solidification methods. A literature search found no available field data on air emissions at Superfund sites using this type of remediation technology. Laboratory studies, however, have estimated that 70-90% of the volatile contaminants in the treated waste eventually evaporate. Experiments also show that most of the loss occurs within 60 minutes of mixing the waste with binding agents.

There are several alternative approaches for estimating the emissions from S/S processes. The best method is to directly measure the emissions during full-scale or pilot-scale operation. The next best method is to estimate the emissions using predictive equations with site-specific inputs. If site-specific inputs are not available, a conservative estimate can be made using default values for the input parameters. Equations are given below for estimating an average long-term emission rate (Equation 1) and a short-term emission rate

(Equation 2). Equation 2 is the recommended equation for estimating VOC emissions; Equation 1 can be used as a gross check of total emissions.

Average Long-Term VOC Emission Rate (Worst Case)

A simple check of the total emissions potential for the site should be made by dividing the total mass of a given contaminant to be removed by the expected duration of the clean-up:

$$ER = (S_v)(C)(\beta)(1) / t_r \quad (\text{Eq. 1})$$

where ER = Average worst case emission rate (g/sec);
S_v = Volume of contaminated soil to be treated (m³);
C = Average contaminant concentration (μg/g);
β = Bulk density of soil (g/cm³);
1 = Constant (g/10⁶μg * 10⁶cm³/m³); and
t_r = Duration of remediation (sec).

The volume of contaminated soil and the total mass of each contaminant of concern present are typically determined during the remedial investigation (RI) of the site, while the fraction of contaminated soil that must be treated is typically determined during the feasibility study (FS) of the site. Final clean-up criteria should also be considered when calculating the volume of soil to be treated. The duration of the clean-up will usually be limited by the operational rate of the treatment process. For Equation 1, a typical default value for bulk density of uncompacted soil is 1.5 g/cm³. The following section contains an empirical equation for estimating a short-term emission rate.

Short-Term VOC Emission Rate

VOC emissions from stabilization and solidification processes can be estimated using a mass-balance approach. The following equation is applicable to ex-situ solidification/stabilization processes:

$$ER = C Q (2.78 \times 10^{-7})(V/100) \quad (\text{Eq. 2})$$

where ER = Emission rate of contaminant i (g/sec);
 C = Concentration of contaminant i in soil ($\mu\text{g/g}$);
 Q = Treatment (feed) rate of soil (kg/hr);
 2.78×10^{-7} = Conversion factor ($\text{g/kg} \cdot \text{g}/\mu\text{g} \cdot \text{hr/sec}$); and
 V = Fraction of contaminant i volatilized (%).

The same equation can be used for in-situ processes, if the treatment rate, Q, is calculated as follows:

$$Q = Q' \beta 1000 \quad (\text{Eq. 3})$$

where Q' = Treatment (feed) rate of soil (m^3/hr);
 β = Bulk density of soil (g/cm^3); and
 1000 = Conversion factor ($\text{kg/g} \cdot \text{cm}^3/\text{m}^3$).

Site-specific field data must be collected (e.g., during the RI/FS) to provide the input data necessary to generate reasonably accurate estimates of air emissions. The only field data required is knowledge of the specific contaminants present in the soil or waste to be stabilized or solidified and the average contaminant concentration. The treatment rate of the unit can be obtained from the vendor or estimated from design documents and the results of any feasibility study. The fraction of VOCs that will be stripped during the process will be highly dependent on the system design and operating procedures. Field test data should be obtained to estimate this parameter. The concentration of contaminant in the soil or sludge to be treated should be available from remedial investigation studies.

The major limitation of these equations is the lack of air emissions data available for developing default values for the term in the model for the percent of VOCs lost from the process. Only one field study⁶ and two laboratory studies^{7,8,9} of air emissions from these processes have been identified, though a third study¹⁰ does provide some useful performance data. These studies show that from 40 to 100% of the VOCs present in the waste are lost during the mixing step of the processes. Essentially all of the VOCs are lost to the atmosphere by the end of the curing step.

Table 1 gives default values to be used in Equations 1, 2, and 3. Feed rates vary widely; values of 5 to 130 tons/hr have been published for ex-situ processes and 25 to 100 tons/hr for in-situ processes. Information is given in Table 1 for estimating emissions of semi-volatile organic compounds (SVOCs). Organic compounds can be divided based on vapor pressure at 25°C.

VOCs = Vapor Pressure $\geq$ 1 mm Hg; and
SVOCs = Vapor Pressure $<$ 1 mm Hg.

Vapor pressure data for organic compounds can be found in Appendices A and B.

ESTIMATION OF PARTICULATE MATTER AIR EMISSIONS

The emissions of PM from stabilization and solidification have been found to be over 1 kg/hr for full-scale operations⁶. No models, however, are available for estimating PM emissions from the processing step of stabilization and solidification operations. An emission factor has been published that can be converted into an emission estimation equation¹³:

$$ER = (0.05)(Q)(2.78 \times 10^{-4}) \quad (\text{Eq. 4})$$

where ER = Emissions (g/sec);
0.05 = Emission factor (g/kg);
Q = Treatment rate (kg/hr); and
 2.78×10^{-4} = Conversion factor (hr/sec).

Emissions from materials handling operations such as excavation, storage, and reagent transfer also should be considered when addressing air impacts from the total site operations. Procedures for estimating these emissions can be found in Reference 4.

Table 1

Default Values for Estimating Emissions From Solidification/Stabilization

Parameter	Symbol	Units	Default Value	Expected Range	Reference
Feedrate	Q	kg/hr	45,000	4,500-120,000 (ex-situ) 23,000-91,000 (in-situ)	10 11
Bulk density of soil	β	g/cm ³	1.5	1.0 - 2.0	12
% Volatilized (VOCs)	V	%	80 ^a 100 ^b	40-100 ^a 100 ^b	9 9
% Volatilized (Semi-Volatiles)	V	%	5 ^a	0-5	Author's Estimate ^c

^aDuring mixing

^bAfter 40 days of curing

^cBased on very limited data adapted from Reference 6

PM emissions from the transfer of the stabilized waste can be estimated as¹⁴:

$$E = \frac{0.00056 \left(\frac{U}{2.2} \right)^{1.3} (M)}{\left(\frac{X_{H_2O}}{2} \right)^{1.4}} \quad (\text{Eq. 5})$$

where E = Emissions (g);
 0.00056 = Empirical factor (g/kg);
 U = Wind speed (m/sec);
 2.2 = Empirical factor (m/sec);
 M = Mass of material handled (kg);
 X_{H₂O} = Moisture fraction (%); and
 2 = Empirical factor (%).

The output from Equation 5 can be converted into an emission rate by dividing by the expected duration of the transfer operations. The minimum field data required to estimate emissions using Equation 5 are the soil moisture content and the mass of material handled. Default values for use with equations 4 and 5 are given in Table 2.

If the dust is contaminated, the PM emissions from Equation 4 or 5 may be translated to emission rates of the contaminant as follows:

$$E_i = X_i E \quad (\text{Eq. 6})$$

where E_i = Emissions of contaminant i (g); and
 X_i = Fraction of contaminant i in particulate matter (unitless).

In general, the dust and silt at a site will contain a higher fraction of the metal species than the bulk soil at the site; i.e. the particulate matter is enriched with the metals¹³.

Table 2.

Default Values for Estimating PM Emissions from S/S Processes

Parameter	Symbol	Units	Default Value	Expected Range	Reference
Treatment rate	Q	kg/hr	45,000	4,500 - 120,000 (ex-situ)	10
				23,000 - 91,000 (in-situ)	11
Wind speed	U	m/sec	4.4	0.6 - 6.7	14
Moisture fraction	X _{H₂O}	%	2	0.25 - 4.8	14

Therefore, X_i is equal to:

$$X_i = C Z 10^{-6} \quad (\text{Eq. 7})$$

where C = Concentration of metal in the bulk soil ($\mu\text{g/g}$);
Z = Enrichment factor (unitless); and
 10^{-6} = Conversion factor ($\text{g}/\mu\text{g}$).

Table 3 contains default values of metal enrichment factors for use in Equation 7. The minimum data needed from RI/FS or other site investigations is the identity and average concentration of metal species in the soil or sludge. In addition to metals, particulate matter also may contain SVOCs. Equation 6 is applicable for SVOCs as well as metals. The equations presented in this section are all empirically based and drawn from measurements at actual sites; they are meant to predict the behavior of average sites. If a particular site has unusual meteorological conditions, rubble, debris, or soils with high silt content, etc., the accuracy of these models may be affected. It is prudent to always monitor actual field emissions, at least from some test location, to verify the model predictions.

ESTIMATION OF AMBIENT AIR CONCENTRATIONS

Estimates of short-term, worst-case ambient concentrations should be obtained by using site specific release parameters in the EPA's TSCREEN model¹⁵. Estimates of long term concentrations should be obtained by using EPA's Industrial Source Complex (ISCLT) model. Here, for simplicity, the annual average estimates are derived by multiplying the short term estimate obtained from the TSCREEN model, by a conversion factor to account for variations of wind direction over time. This approach results in a higher estimate of the annual average concentration than if the ISCLT model, with site specific data, is used.

Table 4 presents three remediation scenarios that address both ex-situ and in-situ processes. The scenarios were developed based on a review of the existing literature.

Table 3.

Metal Concentration and Enrichment Data (Z)

CAAA* Metals	Median Enrichment Factor (Z)
Antimony (Sb)	--
Arsenic (As)	1.28
Beryllium (Be)	--
Cadmium (Cd)	1.31
Chromium (Cr)	4.72
Cobalt (Co)	--
Lead (Pb)	7.34
Manganese (Mn)	--
Mercury (Hg)	3.00
Nickel (Ni)	--
Selenium (Se)	2.00
Other Metals	
Barium (Ba)	1.85
Silver (Ag)	1.00

Source: Reference 14

*CAAA = Clean Air Act Amendments of 1990

Table 4.

Example Scenarios for Stabilization or Solidification

Parameter	Units	Scenario
<u>Ex-Situ Processes</u>		
Treatment Unit:		
Dimensions	m	5x5x2
Area	m ²	25
Release height	m	2
<u>In-Situ Processes</u>		
Treatment Area:		
Dimensions	m	10x10
Area	m ²	100
Release Height	m	1

Figure 2 can be used to estimate the maximum hourly ambient air concentration for an emission rate of 1 gram per second at selected distances downwind from a treatment site. Of the variables listed in Table 4, only the physical dimensions of the treatment area factors into the estimated downwind dispersion. The curves were calculated according to the following assumptions: 1) the combined emission rate is 1 gram per second; 2) a flat terrain without any structures near the treatment site; 3) the emission plume is of low, positive buoyancy; 4) the only downwash structure is the ex-situ treatment unit; 5) the emissions are uniformly distributed over the emitting area and constant over time; and 6) the receptors are at ground level. The dispersion model used is not reliable for estimating air concentrations close-in to area sources. Estimates should not be made for any downwind location that is closer to the source than the side length of the source.

If a given source is larger than the example scenario, Figure 2 may still be used. The dispersion factor, in micrograms/m³ per g/sec, obtained from Figure 2 can be substituted into Equation 8 to estimate the maximum hourly ambient concentration and into Equation 9 to estimate the annual average ambient air concentration for a given downwind distance. Since TSCREEN provides maximum short-term estimates, the factor of 0.08 in Equation 9 is used to convert the short-term estimate to an annual average estimate.

$$C_m = (ER)(F) \quad (\text{Eq. 8})$$

$$C_a = (ER)(F)(0.08) \quad (\text{Eq. 9})$$

where C_m = Maximum hourly ambient air concentration($\mu\text{g}/\text{m}^3$);
 C_a = Annual average ambient air concentration ($\mu\text{g}/\text{m}^3$);
 ER = Emission rate (g/sec); and
 F = Dispersion Factor from Figure 2 ($\mu\text{g}/\text{m}^3/\text{g}/\text{sec}$).

The 0.08 factor in Equation 9 was developed by the U.S. EPA for point sources. This factor has recently been revised and it is still under review by EPA and may be subject to further change. There is no EPA policy for converting from hourly to annual estimates for area sources. Various factors have been published that range up to 0.08.¹⁶ Factors up to 0.20 have been suggested for certain specific locations¹⁷. Graphical estimation tools in lieu

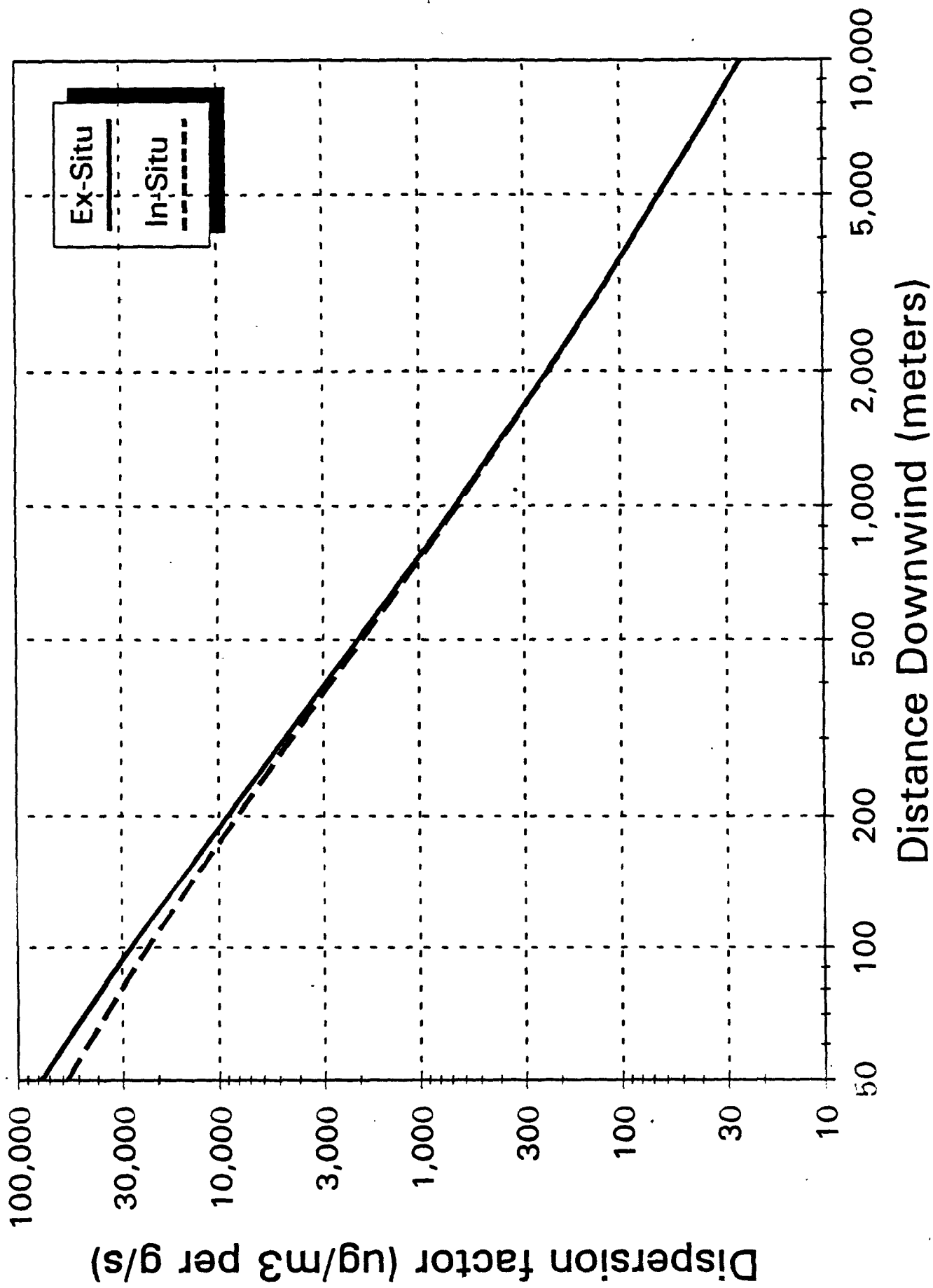


Figure 2. One-Hour Average Downwind Dispersion Factor Versus Distance for Stabilization/Solidification Processes With No Air Controls

of these factors also have been proposed.^{13,18} It is assumed that this point source factor can be applied to area sources without greatly increasing the overall uncertainty of the air impact estimate. As previously stated, the recommended approach is to use ISCLT to estimate long-term concentrations.

ESTIMATION OF HEALTH EFFECTS

Cancer Effects Due to Long-Term Exposure

Potential cancer effects resulting from long-term exposure to substances emitted to the air can be evaluated using inhalation unit risk factors. Inhalation unit risk factors are a measure of the cancer risk for each $\mu\text{g}/\text{m}^3$ of concentration in the ambient air. They are available on EPA's Integrated Risk Information System (IRIS), the Agency's preferred source of toxicity information. User Support can be contacted at (513) 569-7254. The next best source of inhalation unit risk factors is EPA's Health Effects Assessment Summary Tables (HEAST) which are updated annually.¹⁹ Inhalation unit risk factors listed in IRIS as of January 1993 or in HEAST (FY 1992) are given in Table 5 for 168 volatile and semi-volatile organic compounds. This is an updated version of the same table contained in References 2 and 3. Similar information is given in Tables 6 and 7 for selected semi-volatile organic compounds and metals, respectively.

Equation 10 can be used to estimate the cancer risk at a specified distance downwind of the excavation area. Cancer risk is a measure of the increased probability of developing cancer in a lifetime as a result of the exposure in question. Equation 10 assumes continuous exposure (24 hours/day, 365 days/year for 70 years) to the estimated annual average concentration in air.

$$R = (C_a)(IUR) \quad (\text{Eq. 10})$$

Table 5.

Long-Term and Short-Term Health-Based Action Levels for Organic Compounds in Ambient Air

No.	Chemical	CAS Number	Carcinogenicity ^a Inhalation Unit Risk 1/(μg/m ³)	Chronic Toxicity ^a Inhalation RfC (mg/m ³)	Long-Term Action Levels				Short-Term Action Levels ^d Lowest OEL/100 (μg/m ³)
					Risk-Specific Concentrations for Carcinogenicity 10 ⁻⁶ 70-year Risk (μg/m ³)	RfC-Based Concentrations for Non-Carcinogenic Effects (μg/m ³)	Concentrations Based on Occupational Exposure ^d Lowest OEL/1000 (μg/m ³)		
1	Acetaldehyde	75-07-0	2.2e-06 ^c	9e-03 ^c	0.45	9	180	1,800	
2	Acetic Acid	64-19-7	—	—	—	—	25	250	
3	Acetic anhydride	108-24-7	—	—	—	—	20	200	
4	Acetone	67-64-1	— ^{c,e}	(4e-01) ^b	—	400	1,780	17,800	
5	Acetonitrile	75-05-8	— ^c	5e-02 ^f	—	50	67	670	
6	Acrolein	107-02-8	— ^{c,e}	2e-05 ^e	—	0.02	0.23	2.30	
7	Acrylic acid	79-10-7	— ^c	3e-04 ^e	—	0.3	5.90	59	
8	Acrylonitrile	107-13-1	6.8e-05 ^c	2e-03 ^c	0.015 ^c	2	4.30	43	
9	Allyl alcohol	107-18-6	— ^c	(2e-02) ^b	—	20	4.80	48	
10	Allyl chloride	107-05-1	— ^{c,e}	1e-03 ^c	—	1	3.00	30	
11	Aniline	62-53-3	1.6e-6 ^b	1e-03 ^c	0.63	1	7.60	76	
12	Anthracene	120-12-7	— ^{c,e}	(1e+00) ^b	—	1,000	0.20	2.00	
13	Benzaldehyde	100-52-7	— ^c	(4e-01) ^b	—	400	—	—	
14	Benzene	71-43-2	8.3e-06 ^c	— ^c	0.12	—	32	320	
15	Benzoic acid	65-85-0	— ^{c,e}	(1.4e+01) ^b	—	14,000	—	—	
16	Benzyl alcohol	100-51-6	— ^c	(1e+00) ^b	—	1,000	—	—	
17	Benzyl chloride	100-44-7	5e-05 ^b	— ^c	0.02	—	5	50	
18	Bromoform	75-25-2	1.1e-06 ^c	(7e-02) ^b	0.91	70	5	50	
19	1,3-Butadiene	106-99-0	2.8e-04 ^c	— ^c	3.6e-03	—	22	220	
20	n-Butane	106-97-8	—	—	—	—	1,900	19,000	
21	2-Butanol	15892-23-6	—	—	—	—	303	3,030	
22	n-Butanol	71-36-3	— ^{c,e}	(4e-01) ^b	—	400	152	1,520	

Table 5.
(Continued)

No.	Chemical	CAS Number	Carcinogenicity ^a	Chronic Toxicity ^c	Long-Term Action Levels				Short-Term Action Levels ^d
					Inhalation Unit Risk 1/($\mu\text{g}/\text{m}^3$)	Risk-Specific Concentrations for Carcinogenicity 10 ⁻⁶ 70-year Risk ($\mu\text{g}/\text{m}^3$)	RfC-Based Concentrations for Non-Carcinogenic Effects ($\mu\text{g}/\text{m}^3$)	Concentrations Based on Occupational Exposure ^d	
23	n-Butyl-Acetate	123-86-4	-	-	-	-	710	7,100	
24	Tert-Butyl-Alcohol	75-65-0	-	-	-	-	300	3,000	
25	Carbon disulfide	75-15-0	- ^e	1e-02 ^f	-	10	12	120	
26	Carbon Tetrachloride	56-23-5	1.5e-05 ^e	(2.5e-03) ^b	0.0067	2.5	12.6	126	
27	Carbonyl Sulfide	463-58-1	- ^e	- ^e	-	-	-	-	
28	Catechol	120-80-9	- ^e	- ^e	-	-	20	200	
29	Chlorine	7782-50-5	- ^e	- ^e	-	-	1.5	15	
30	Chlorobenzene	108-90-7	- ^{e,g}	2e-02 ^f	-	20	46	460	
31	Chlorodifluoromethane	75-45-6	- ^e	- ^e	-	-	3,540	35,400	
32	Chloroform	67-66-3	2.3e-05 ^e	(4e-02) ^b	0.043	40	9.78	98	
33	Chloromethyl methyl ether	107-30-2	- ^e	- ^e	-	-	-	-	
34	Chloropentafluoroethane	76-15-3	-	-	-	-	6,320	63,200	
35	Chloroprene	126-94-8	- ^e	7e-03 ^f	-	7	35	350	
36	m-Cresol	108-39-4	- ^{e,g}	(2e-01) ^b	-	200	22	220	
37	o-Cresol	95-48-7	- ^{e,g}	(2e-01) ^b	-	200	22	220	
38	p-Cresol	106-44-5	- ^{e,g}	(2e-01) ^b	-	200	22	220	
39	Cyanogen	460-19-5	- ^e	(1.4e-01) ^b	-	140	20	200	
40	Cyclohexane	110-82-7	-	-	-	-	1,030	10,300	
41	Cyclohexanol	108-93-0	-	-	-	-	200	2,000	
42	Cyclohexanone	108-94-1	- ^e	(18) ^b	-	18,000	100	1,000	
43	Cyclohexene	110-83-8	-	-	-	-	1,010	10,100	
44	Cyclopentane	287-92-3	-	-	-	-	1,720	17,200	
45	Diazomethane	334-88-3	- ^e	- ^e	-	-	0.34	3.4	

Table 5.
(Continued)

No.	Chemical	CAS Number	Carcinogenicity ^a	Chronic Toxicity ^a	Long-Term Action Levels				Short-Term Action Levels ^d
					Inhalation Unit Risk 1/(μg/m ³)	Risk-Specific Concentrations for Carcinogenicity 10 ⁻⁶ 70-year Risk (μg/m ³)	RfC-Based Concentrations for Non-Carcinogenic Effects (μg/m ³)	Concentrations Based on Occupational Exposure ^d	
46	Dibutyl-O-Phthalate	84-74-2	— ^{aa}	(4e-01) ^b	—	400	5.00	50	50
47	o-Dichlorobenzene	95-50-1	— ^{aa}	2e-01 ^f	—	200	150	1,500	1,500
48	p-Dichlorobenzene	106-46-7	6.6e-6 ^b	8e-01 ^f	0.15	800	450	4,500	4,500
49	Dichloroethylether	111-44-4	3.3e-04 ^c	—	3.0e-03	—	29	290	290
50	Dichlorodifluoromethane	75-71-8	— ^e	(0.7) ^b	—	200	4,950	49,500	49,500
51	1,1-Dichloroethane	75-34-3	— ^{aa}	5e-01 ^f	—	500	400	4,000	4,000
52	1,2-Dichloroethane	107-06-2	2.6e-05 ^c	—	0.038 ^e	—	4.00	40	40
53	1,1-Dichloroethylene	75-35-4	5e-05 ^c	(3e-02) ^b	0.020	30	4.00	40	40
54	cis-1,2-dichloroethylene	156-59-2	— ^{aa}	(4e-02) ^b	—	40	790	7,900	7,900
55	trans-1,2-dichloroethylene	156-60-5	— ^e	(7e-02) ^b	—	70	790	7,900	7,900
56	Dichloromethane	75-09-2	4.7e-07 ^c	3e+00 ^f	2.1	3,000	174	1,740	1,740
57	Dichloromono-fluoromethane	75-43-4	—	—	—	—	40	400	400
58	1,2-Dichloropropane	78-87-5	2e-05 ^b	4e-3 ^c	0.050	4	347	3,470	3,470
59	1,3-Dichloropropene	542-75-6	3.7e-05 ^f	2e-02 ^c	0.027	20	4.5	45	45
60	1,2-Dichloro-1,1,2,2-Tetrafluoroethane	76-14-2	—	—	—	—	6,990	69,900	69,900
61	Diethanolamine	111-42-2	—	—	—	—	13	130	130
62	Diethyl amine	109-89-7	—	—	—	—	30	300	300
63	N,N-Dimethylaniline	121-69-7	— ^e	(7e-03) ^b	—	7	25	250	250
64	Diethyl ether	60-29-7	—	(7e-01) ^b	—	700	1,200	12,000	12,000
65	Dimethylamine	124-40-3	— ^e	— ^e	—	—	9.2	92	92
66	Dimethyl formamide	68-12-2	— ^e	3e-02 ^c	—	30	30	300	300
67	1,1-Dimethyl hydrazine	57-14-7	1e-03 ^f	— ^e	1e-03	—	1	10	10
68	2,4-Dinitrophenol	51-28-5	— ^e	(7e-03) ^b	—	7	—	—	—

Table 5.
(Continued)

No.	Chemical	CAS Number	Carcinogenicity ^a Inhalation Unit Risk 1/(μg/m ³) ^b	Chronic Toxicity ^a Inhalation RfC (mg/m ³) ^b	Long-Term Action Levels				Short-Term Action Levels ^d Lowest OEL/100 (μg/m ³)
					Risk-Specific Concentrations for Carcinogenicity		RfC-Based Concentrations for Non-Carcinogenic Effects (μg/m ³)	Concentrations Based on Occupational Exposure ^d Lowest OEL/1000 (μg/m ³)	
					10 ⁻⁶ 70-year Risk (μg/m ³)				
69	1,4-Dioxane	123-91-1	3.1e-03 ^b	— ^c	3.2e-04	—	90	900	
70	Diphenyl	92-52-4	— ^c	(1.8e-01) ^b	—	180	1.00	10	
71	Epichlorohydrin	106-89-8	1.2e-06 ^c	1e-3 ^c	0.83	1.0	7.6	76	
72	1,2-Epoxybutane	106-88-7	— ^c	2e-02 ^c	—	20	—	—	
73	Ethanol	64-17-5	—	—	—	—	1,880	18,800	
74	Ethyl acetate	141-78-6	— ^c	(3.2e+00) ^b	—	3,200	1,400	14,000	
75	Ethyl acrylate	140-88-5	1.4e-05 ^b	— ^c	0.071	—	20	200	
76	Ethyl amine	75-04-7	—	—	—	—	18	180	
77	Ethylbenzene	100-41-4	— ^c	1e-00 ^c	—	1,000	434	4,340	
78	Ethyl bromide	74-96-4	— ^c	— ^c	—	—	22	220	
79	Ethyl carbamate	51-79-6	— ^c	— ^c	—	—	—	—	
80	Ethyl chloride	75-00-3	— ^c	1e+01 ^c	—	10,000	2,600	26,000	
81	Ethylenediamine	107-15-3	— ^c	0.07	—	70	25	250	
82	Ethylene dibromide	106-93-4	2.2e-04 ^c	— ^c	4.5e-03	—	—	—	
83	Ethylene glycol	107-21-1	— ^c	(7.0e+00) ^b	—	7,000	127	1,270	
84	Ethylene imine	151-56-4	— ^c	—	—	—	0.88	8.80	
85	Ethylene oxide	75-21-8	1.0e-04 ^c	(3.6e+00) ^b	0.010	3,600	1.80	18	
86	Formaldehyde	50-00-0	1.3e-05 ^c	(7e-01) ^b	0.077	700	1.2	12	
87	Formic Acid	64-18-6	— ^c	(7e+00) ^b	—	7,000	9.00	90	
88	Furan	110-00-9	— ^c	(4.0e-03) ^b	—	4	—	—	
89	Glycerol	56-81-5	—	—	—	—	5.00	50	
90	n-Heptane	142-82-5	— ^c	— ^c	—	—	1,600	16,000	
91	n-Hexane	110-54-3	— ^c	2e-01 ^c	—	200	176	1,760	

Table 5.
(Continued)

No.	Chemical	CAS Number	Carcinogenicity ^a Inhalation Unit Risk 1/(μg/m ³)	Chronic Toxicity ^a Inhalation RfC (mg/m ³)	Long-Term Action Levels				Short-Term Action Levels ^d Lowest OEL/100 (μg/m ³)
					Risk-Specific Concentrations for Carcinogenicity 10 ⁻⁶ 70-year Risk (μg/m ³)	RfC-Based Concentrations for Non-Carcinogenic Effects (μg/m ³)	Concentrations Based on Occupational Exposure ^d Lowest OEL/1000 (μg/m ³)		
92	Hydrazine	302-01-2	4.9e-03 ^e	— ^e	2.0e-04	—	0.1	1	
93	Hydrochloric acid	7647-01-0	— ^e	7e-03 ^e	—	7	7.5	75	
94	Hydrogen cyanide	74-90-8	— ^e	(0.07) ^b	—	70	11	110	
95	Hydrogen Sulfide	7783-06-4	— ^e	9e-04 ^e	—	0.9	14	140	
96	Isobutanol	78-83-1	—	(1.1e+00) ^b	—	1,100	150	1,500	
97	Isobutyl acetate	110-19-0	—	—	—	—	700	7,000	
98	Isopropyl alcohol	67-63-0	— ^e	— ^e	—	—	983	9,830	
99	Isopropyl amine	75-31-0	—	—	—	—	12	120	
100	Isopropylbenzene	98-82-8	— ^e	(1.4e-01) ^b	—	140	245	2,450	
101	Methanol	67-56-1	— ^e	(2e+00) ^b	—	2,000	260	2,600	
102	Methyl acetate	79-20-9	— ^e	(4e+00) ^b	—	4,000	606	6,060	
103	Methyl acrylate	96-33-3	— ^{ee}	(1.1e-01) ^b	—	110	35	350	
104	Methyl amine	74-89-5	—	—	—	—	6.4	64	
105	Methyl bromide	74-83-9	— ^{ee}	5e-3 ^e	—	5	19	190	
106	Methyl-tert-butyl-ether	1634-04-4	— ^e	5e-01 ^e	—	500	—	—	
107	Methyl chloride	74-87-3	1.8e-06 ^e	— ^e	0.55	—	103	1,030	
108	Methylcyclohexane	108-87-2	—	3e+00 ^e	—	3,000	1,600	16,000	
109	Methyl-ethyl-ketone	78-93-3	— ^{ee}	1e-00 ^e	—	1,000	590	5,900	
110	Methyl formate	107-31-3	—	—	—	—	246	2,460	
111	Methyl hydrazine	60-34-4	3e-04 ^b	— ^e	3.3e-03	—	0.38	3.8	
112	Methyl iodide	74-88-4	— ^e	— ^e	—	—	10	100	
113	Methyl-Isobutyl-Ketone	108-10-1	— ^e	8e-02 ^f	—	80	205	2,050	
114	Methyl isocyanate	624-83-9	— ^e	— ^e	—	—	0.047	0.47	

Table 5.
(Continued)

No.	Chemical	CAS Number	Carcinogenicity ^a Inhalation Unit Risk 1/($\mu\text{g}/\text{m}^3$)	Chronic Toxicity ^a Inhalation RfC (mg/m ³)	Long-Term Action Levels				Short-Term Action Levels ^d Lowest OEL/100 ($\mu\text{g}/\text{m}^3$)
					Risk-Specific Concentrations for Carcinogenicity 10 ⁻⁴ 70-year Risk ($\mu\text{g}/\text{m}^3$)	RfC-Based Concentrations for Non-Carcinogenic Effects ($\mu\text{g}/\text{m}^3$)	Concentrations Based on Occupational Exposure ^d Lowest OEL/1000 ($\mu\text{g}/\text{m}^3$)		
115	Methyl-Isopropyl-Ketone	563-80-4	-	-	-	-	705	7,050	
116	Methyl mercaptan	74-93-1	- ^e	- ^e	-	-	0.98	98	
117	Methyl methacrylate	80-62-6	- ^e	(3e-01) ^b	-	300	410	4,100	
118	Methyl-n-Propyl-ketone	107-87-9	-	-	-	-	700	7,000	
119	Alpha-methyl-styrene	98-83-9	- ^e	(2.5e-01) ^b	-	250	240	2,400	
120	Monoethanolamine	141-43-5	-	-	-	-	7.50	75	
121	Morpholine	110-91-8	-	-	-	-	70	700	
122	Naphthalene	91-20-3	- ^{ee}	-	-	-	50	500	
123	2-Nitropropane	79-46-9	2.7e-03 ^e	2e-02 ^e	3.7e-04	20	35	350	
124	N-Nitrosodimethylamine	62-75-9	1.4e-02 ^e	- ^e	7.1e-05	-	-	-	
125	N-Nitrosomorpholine	59-89-2	-	-	-	-	-	-	
126	n-Nonane	111-84-2	-	-	-	-	1,050	10,500	
127	n-Octane	111-65-9	-	-	-	-	1,400	14,000	
128	n-Pentane	109-66-0	-	-	-	-	1,770	17,700	
129	Phenanthrene	85-01-9	- ^{ee}	- ^e	-	-	0.20	2	
130	Phenol	108-95-2	- ^{ee}	(2.1e+00) ^b	-	2,000	19	190	
131	Phosgene	75-44-5	- ^e	- ^e	-	-	0.4	4	
132	Phosphine	7803-51-2	- ^e	3e-05 ^f	-	0.03	0.4	4	
133	Phthalic anhydride	85-44-9	- ^e	1.2e-01 ^f	-	120	6.00	60	
134	Propane	74-98-6	-	-	-	-	1,800	18,000	
135	1,2-Propanediol	57-55-6	- ^e	- ^e	-	-	-	-	
136	1-Propanol	71-23-8	- ^e	- ^e	-	-	492	4,920	
137	beta-Propiolactone	57-57-8	- ^e	- ^e	-	-	1.5	15	

Table 5.
(Continued)

No.	Chemical	CAS Number	Carcinogenicity ^a	Chronic Toxicity ^a	Long-Term Action Levels				Short-Term Action Levels ^d
					Risk-Specific Concentrations for Carcinogenicity	RfC-Based Concentrations for Non-Carcinogenic Effects (μg/m ³)	Concentrations Based on Occupational Exposure ^d		
							10 ⁻⁶ 70-year Risk (μg/m ³)	Lowest OEL/1000 (μg/m ³)	
138	Propionaldehyde	123-38-7	—	—	—	—	—	—	—
139	Propionic acid	79-09-4	— ^e	— ^e	—	—	30	30	300
140	n-Propyl-Acetate	109-60-4	—	—	—	—	835	835	8,350
141	Propylene oxide	75-56-9	3.7e-06 ^e	3e-02 ^e	0.27	30	48	48	480
142	1,2-Propylenimine	75-55-8	— ^e	— ^e	—	—	4.7	4.7	47
143	Pyridine	110-86-1	— ^e	(4e-03) ^b	—	4	15	15	150
144	Quinone	106-51-4	— ^e	— ^e	—	—	0.4	0.4	4
145	Styrene	100-42-5	— ^e	1.0e+00 ^e	—	1000	213	213	2,130
146	1,1,1,2-Tetrachloro-2,2-Difluoroethane	76-11-9	—	—	—	—	4,170	4,170	41,700
147	1,1,2,2-Tetrachloroethane	79-34-5	5.8e-05 ^{e,e}	— ^e	0.017	—	6.90	6.90	69
148	Tetrachloroethylene	127-18-4	5.8e-07 ^e	(3.5e-2) ^b	1.7	35	170	170	1,700
149	Tetrahydrofuran	109-99-9	— ^e	— ^e	—	—	590	590	5,900
150	Toluene	108-88-3	— ^{e,e}	4e-01 ^e	—	400	375	375	3,750
151	p-Toluidine	106-49-0	5.4e-05 ^b	— ^e	0.019	—	8.80	8.80	88
152	1,1,1-Trichloroethane	71-55-6	— ^{e,e}	1.0e+00 ^f	—	1,000	1,900	1,900	19,000
153	1,1,2-Trichloroethane	79-00-5	1.6e-05 ^{e,e}	1.4e-02 ^e	0.063	14	45	45	450
154	Trichloroethylene	79-01-6	— ^e	— ^e	—	—	269	269	2,690
155	Trichlorofluoromethane	75-69-4	— ^e	7.0e-01 ^f	—	700	5,620	5,620	56,200
156	1,2,3-Trichloropropane	96-18-4	— ^e	2.0e-02 ^e	—	20	60	60	600
157	1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	— ^e	(2.7e+01) ^b	—	27,000	7,600	7,600	76,000
158	Triethylamine	121-44-8	— ^e	7e-3 ^e	—	7	40	40	400
159	Trifluorobromomethane	75-63-8	—	—	—	—	6,090	6,090	60,900
160	1,2,3-Trimethylbenzene	526-73-8	—	—	—	—	123	123	1,230

Table 5.
(Continued)

No.	Chemical	CAS Number	Carcinogenicity ^a	Chronic Toxicity ^a	Long-Term Action Levels				Short-Term Action Levels ^d
					Inhalation Unit Risk 1/($\mu\text{g}/\text{m}^3$)	Risk-Specific Concentrations for Carcinogenicity	RFC-Based Concentrations for Non-Carcinogenic Effects ($\mu\text{g}/\text{m}^3$)	Concentrations Based on Occupational Exposure ^d	
161	1,2,4-Trimethylbenzene	95-63-6	—	—	—	—	123	1,230	
162	1,3,5-Trimethylbenzene	108-67-8	—	—	—	—	123	1,230	
163	Vinyl acetate	108-05-4	— ^e	2e-01 ^a	—	200	30	300	
164	Vinyl bromide	593-60-2	3.2e-05 ^f	—	0.031	—	20	200	
165	Vinyl-chloride	75-01-4	8.4e-05 ^e	—	0.012	—	2.60	26	
166	m-Xylene	108-38-3	— ^e	(7) ^b	—	7000	434	4,340	
167	o-Xylene	95-47-6	— ^e	(7) ^b	—	7000	434	4,340	
168	p-Xylene	106-42-3	— ^e	— ^c	—	—	434	4,340	

INSTRUCTIONS ON USE:

Read short-term action level directly from last column. For the three columns of long-term action levels, use the 10⁻⁶ risk data, if available, then the RFC data; use the OEL/1000 if no other data exists.

- ^a EPA does not necessarily endorse the use of oral slope factors or oral RfDs to derive inhalation values. These are intended to serve as screening levels only and do not represent EPA guidance.
- ^b Derived based on oral slope factor (or oral RfD).
- ^c Verified, available on IRIS (1/93) or Workgroup concurrence on final database file, and IRIS input pending.
- ^d EPA does not necessarily endorse the use of occupational exposure limits to derive short- and long-term action levels for ambient air. These are intended to serve as screening levels only and do not represent EPA guidance. Intended changes for OEL values are included, where applicable.
- ^e EPA Class C or D carcinogen.
- ^f Available in the Health Effects Assessment Summary Tables (HEAST, FY1992).

Table 6.

Long-Term and Short-Term Health-Based Action Levels for Selected Semi-Volatile Organic Compounds in Air

No.	Chemical	CAS Number	Carcinogenicity ^a Inhalation Unit Risk 1/(μg/m³)	Chronic Toxicity ^a Inhalation RfC (mg/m³) ^b	Long-Term Action Levels				Short-Term Action Levels ^d Lowest OEL/100 (μg/m³)
					Risk-Specific Concentrations for Carcinogenicity 10 ⁻⁶ 70-year Risk (μg/m³)	RfC-Based Concentrations for Non-Carcinogenic Effects (μg/m³)	Concentrations Based on Occupational Exposure ^e		
							Lowest OEL/1000 (μg/m³)		
1	Acenaphthene	83-32-9	-- ^e	(2.1e-01) ^b	--	210	--	--	
2	2-Acetoaminofluorene	53-96-3	--	--	--	--	--	--	
3	2-Acetylfuran	1192-62-7	--	--	--	--	--	--	
4	Benzidine	92-87-5	6.7e-02 ^c	(1.1e-02) ^b	1.5e-05	10.5	--	--	
5	Benz(a)anthracene	56-55-3	-- ^e	-- ^e	--	--	--	--	
6	Benzo(a)pyrene	50-32-8	1.7e-03 ^b	--	5.9e-04	--	0.2 ^f	2.0	
7	Benzo(a)fluoranthene	205-99-2	-- ^e	-- ^e	--	--	--	--	
8	Benzo(g,h,i)perylene	191-24-2	-- ^e	-- ^e	--	--	--	--	
9	Benzo(k)fluoranthene	207-08-9	-- ^e	-- ^e	--	--	--	--	
10	Bis(2-ethylhexyl)phthalate	117-81-7	4e-06 ^b	(7e-02) ^b	0.25	70	5	50	
11	Chlordane	57-74-9	3.7e-04 ^c	(2.1e-04) ^b	2.7e-03	0.21	0.5	5	
12	Chrysene	218-01-9	--	--	--	--	0.2 ^f	2.0 ^g	
13	Cresol	1319-77-3	-- ^{e,g}	(2e-01) ^b	--	200	22	220	
14	Dioxin (2,3,7,8-TCDD)	1746-01-6	--	--	--	--	--	--	
15	Dibenzofuran	132-64-9	-- ^{e,g}	-- ^e	--	--	--	--	
16	Dibenzo(a,h)anthracene	53-70-3	-- ^e	-- ^e	--	--	--	--	
17	Di-n-butylphthalate	84-74-2	-- ^{e,g}	(3.5e-01) ^b	--	350	5	50	
18	Ethylenamine	593-67-9	--	--	--	--	--	--	
19	Fluoranthene	206-44-0	-- ^{e,g}	(1.4e-01) ^b	--	140	--	--	
20	Fluorene	86-73-7	-- ^{e,g}	(1.4e-01) ^b	--	140	--	--	
21	Heptachlor	76-44-8	1.3e-03 ^c	(1.8e-03) ^b	7.7e-04	1.8	0.5	5	

Table 6. (Continued)

No.	Chemical	CAS Number	Carcinogenicity ^a Inhalation Unit Risk 1/(μg/m ³)	Chronic Toxicity ^a Inhalation RfC (mg/m ³)	Long-Term Action Levels				Short-Term Action Levels ^d Lowest OEL/100 (μg/m ³)
					Risk-Specific Concentrations for Carcinogenicity 10 ⁻⁴ 70-year Risk (μg/m ³)	RfC-Based Concentrations for Non-Carcinogenic Effects (μg/m ³)	Concentrations Based on Occupational Exposure ^d		
							Lowest OEL/1000 (μg/m ³)		
22	Hexachlorocyclopentadiene	77-47-4	-- ^e	7e-5 ^f	--	0.07	0.1	1.0	
23	Indeno(1,2,3,CD)pyrene	193-39-5	--	--	--	--	--	--	
24	Lindane	58-89-9							
25	Maleic Anhydride	108-31-6	-- ^e	(3.5e-01) ^b	--	350	1	10	
26	2-Methylnaphthalene	91-57-6	--	--	--	--	--	--	
27	p-Nitrosodiphenylamine	156-10-5	--	--	--	--	--	--	
28	Nitrobenzene	98-95-3	-- ^e	2e-3	--	2.0	5	50	
29	PCBs	1336-36-3	2.2e-03 ^b	-- ^e	4.5e-04	--	--	--	
30	PAHs	--	--	--	--	--	0.2 ^e	2.0 ^e	
31	Parathion	56-38-2	-- ^e	(2.1e-02) ^b	--	21	0.1	1.0	
32	Pyrene	129-00-0	-- ^e	(1.1e-01) ^b	--	105	--	--	
33	Tridecane	629-50-5	--	--	--	--	--	--	
34	Undecane	1120-21-4	--	--	--	--	--	--	

INSTRUCTIONS ON USE: Read short-term action level directly from last column. For the three columns of long-term action levels, use the 10-6 risk data, if available, then the RfC data; use the OEL/1000 if no other data exists.

- ^a EPA does not necessarily endorse the use of oral slope factors or oral RfDs to derive inhalation values. These are intended to serve as screening levels only and do not represent EPA guidance.
- ^b Derived based on oral slope factor (or oral RfD).
- ^c Verified, available on IRIS or Workgroup concurrence on final database file, and IRIS input pending.
- ^d EPA does not necessarily endorse the use of occupational exposure limits to derive short- and long-term action levels for ambient air. These are intended to serve as screening levels only and do not represent EPA guidance. Intended changes for OEL values are included, where applicable.
- ^e EPA Class C or D carcinogen.
- ^f Available in the Health Effects Assessment Summary Tables (HEAST, FY 1992).
- As coal tar pitch volatiles.

Table 7.

Long-Term and Short-Term Health-Based Action Levels for Metals in Ambient Air

No.	Chemical	CAS Number	Carcinogenicity ^a Inhalation Unit Risk 1/(μg/m ³)	Chronic Toxicity ^a Inhalation RfC (mg/m ³)	Long-Term Action Levels				Short-Term Action Levels ^d Lowest OEL/100 (μg/m ³)
					Risk-Specific Concentrations for Carcinogenicity 10 ⁻⁶ 70-year Risk (μg/m ³)	RfC-Based Concentrations for Non-Carcinogenic Effects (μg/m ³)	Concentrations Based on Occupational Exposure ^d		
							Lowest OEL/1000 (μg/m ³)		
1	Antimony	7440-36-0	ND	(1.4+00) ^b	--	1,400	0.50	5.00	
2	Arsenic	7740-38-2	4.3e-03 ^c	(1.0e+00) ^b	2.3e-04	1,050	0.20	2.00	
3	Beryllium	7440-41-7	2.4e-03 ^c	(1.7e+01) ^b	4.2e-04	17,500	0.002	0.02	
4	Cadmium	7440-43-9	1.8e-03 ^c	(3.5e+00) ^b	5.6e-04	3,500	0.05	0.50	
5	Chromium III	7440-47-3	ND	(3.5+03) ^b	--	3,500,000	0.50	5.00	
6	Chromium IV	7440-47-3	1.2e-02 ^c	(1.7e+01) ^b	8.3e-05	17,500	0.05	0.50	
7	Cobalt	7440-48-4	ND	ND	--	--	0.05	0.50	
8	Lead	7439-92-1	ND	ND	--	--	0.15	1.50	
9	Manganese	7439-96-5	ND ^{**}	4e-04 ^c	ND	0.40	0.50	5.00	
10	Mercury (vapor)	7439-97-6	ND ^{**}	3e-04 ^c	ND	0.30	0.05	0.50	
11	Nickel	7440-02-0	2e-04 ^c	(7.0e+01) ^b	5.0e-03	70,000	1.00	10.00	
12	Selenium	7782-49-2	ND ^c	(1.7e+01) ^b	--	17,500	0.20	2.00	

INSTRUCTIONS ON USE:

Read short-term action level directly from last column. For the three columns of long-term action levels, use the 10-6 risk data, if available, then the RfC data; use the OEL/1000 if no other data exists.

- ^a EPA does not necessarily endorse the use of oral slope factors or oral RfDs to derive inhalation values. These are intended to serve as screening levels only and do not represent EPA guidance.
- ^b Derived based on oral slope factor (or oral RfD).
- ^c Verified, available on IRIS or Workgroup concurrence on final database file, and IRIS input pending.
- ^d EPA does not necessarily endorse the use of occupational exposure limits to derive short- and long-term action levels for ambient air. These are intended to serve as screening levels only and do not represent EPA guidance. Intended changes for OEL values are included, where applicable.
- ^e EPA Class C or D carcinogen.

R is the cancer risk from long-term exposure to a specific compound in air, (unitless); C_a is the annual average ambient concentration estimated from Equation 9, ($\mu\text{g}/\text{m}^3$); IUR is the inhalation unit risk factor, ($\mu\text{g}/\text{m}^3$)⁻¹ obtained from Tables 5, 6, or 7.

If the source operates for less than 70 years, multiply C_a by $x/70$, where x is the expected operating time of the source in years before using Equation 10. If more than one contaminant is present, the cancer risks for each contaminant can be summed to derive the total cancer risk at a specified distance downwind of the source.

Non-Cancer Effects Due to Long-Term Exposure

Non-cancer effects can be evaluated by using chronic inhalation reference concentrations (RfCs). An inhalation RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of continuous exposure of the human population to contaminants in the air that is likely to be without appreciable risk of deleterious effects during a lifetime. During the past three years, the EPA has become increasingly active in the development of chemical specific RfCs.

If inhalation RfCs were not available from either IRIS or HEAST, then chronic oral reference dose (RfD) data (in mg/kg/day) were multiplied by 70 kg (average body weight of an adult), then divided by 20 m³/day (average adult inhalation rate), and finally multiplied by 1000 $\mu\text{g}/\text{mg}$ to derive a value in $\mu\text{g}/\text{m}^3$. This methodology was selected for this screening document. The EPA, however, does not condone derivation of RfCs from data for other routes of exposure on a chemical specific basis.

The EPA considers the minimum basis for the derivation of an RfC to be a properly conducted inhalation study that examines portal of entry effects. Portal of entry effects are particularly important with respect to inhalation. There are many known cases where respiratory effects due to inhalation exposure are much more severe than effects resulting from equivalent oral doses. Therefore, ambient air action levels based on extrapolated oral

data should be used cautiously since there may be significant differences between the oral and inhalation exposure pathways.

For compounds lacking RfC or RfD values, action levels were based on occupational exposure levels recommended by the Occupational Safety and Health Administration (OSHA)²⁰ and the American Conference of Governmental Industrial Hygienists (ACGIH)²¹. The action levels were estimated by using the lower of the OSHA Permissible Exposure Limit-Time Weighted Average (PEL-TWA) level (or ceiling value) or the ACGIH Threshold Limit Value-Time Weighted Average (TLV-TWA) level (or ceiling value). The lower value was divided by 1000 to compensate for differences between occupational and residential exposures. It should be noted that occupational exposure levels are not intended for evaluation or control of community air pollution or in estimating the toxic potential of continuous, uninterrupted exposures. Therefore, ambient air action levels based on occupational exposure limits are not precise distinctions between safe and dangerous ambient air concentrations, nor are they necessarily indices of toxicity.

Long-term ambient air action level concentrations for non-carcinogens based on RfCs, extrapolated RfDs and occupational exposure levels are also listed in Tables 5, 6, and 7. The action levels are in units of $\mu\text{g}/\text{m}^3$ to facilitate comparison to the ambient air concentrations estimated from Equation 9.

Short-Term Exposure

The short-term (one hour) action levels, in $\mu\text{g}/\text{m}^3$, are presented in the last column of Tables 5, 6, and 7. The listed values were obtained by dividing the lowest of (1) the OSHA PEL-TWA or (2) the ACGIH TLV-TWA (or ceiling limits if 8-hour averages are not available) by 100. Division by 100 accounts for variations in human sensitivity (occupational levels are designed to protect healthy adult workers) and for uncertainties in using occupational exposure levels to derive ambient air action levels.

The occupational exposure levels on which the short-term action levels are based are subject to change. To check the values in Tables 5, 6, and 7 (or to derive values for compounds not listed in the tables), determine the current OSHA PEL-TWA values by consulting 29 CFR Section 1910 and the most recent edition of the ACGIH publication entitled Threshold Limit Values and Biological Exposure Indices.

The short-term action levels listed in Tables 5, 6, and 7 can be compared directly with the estimated maximum hourly ambient air concentrations obtained by using Equation 8 and Figure 2. Use of the short term action levels should consider that no EPA accepted method exists to determine the short-term concentrations of airborne chemicals acceptable for community exposure.

EXAMPLE

The following steps illustrate the use of the estimation procedures presented in this document. The goal is to estimate the maximum hourly and annual average ambient air concentrations at the nearest receptor to an S/S area and compare these values to the action level concentrations listed in Tables 5, 6, and 7.

- Step 1** First, collect all necessary information. For this example, assume a site that has approximately 10,000 m³ of soil contaminated with 100 µg/g of lead. The site also contains chloroform and 1,1,1-trichloroethane at concentrations in the soil of 0.01 and 0.05 ug/g, respectively. The material will be treated in-situ using a proprietary stabilization process. The treatment rate has not yet been determined, nor has the need for air emission controls, so a default rate of 45,000 kg/hour and no air emission controls are assumed. The S/S process is expected to be in continual operation for 14 days (1.210×10^6 seconds). The bulk density of the soil at the site averages about 1.5 g/cm³. The nearest off-site downwind receptor is 400 meters away.
- Step 2** Estimate the total emissions potential for the site. Using Equation 1, the worst-case average long-term emission rate of chloroform would be:

$$ER = \frac{(10,000)(0.01)(1.5)(1)}{(1.21 \times 10^6)} = 1.24 \times 10^{-4} \text{ g/sec}$$

The average long-term emission rate for 1,1,1-trichloroethane is 6.20×10^{-4} g/sec, and for lead it is 1.24 g/sec. All these rates assume that 100% of the contaminant is lost to the atmosphere and that all contaminated material is treated.

Step 3 Estimate the VOC emission rate of each compound from the S/S operation. The appropriate data are used with Equations 2 and 3. For chloroform, the emission rate would be:

$$ER = (0.01)(45,000)(2.78 \times 10^{-7})(100/100) = 1.25 \times 10^{-4} \text{ g/sec}$$

The VOC emission rate for 1,1,1-trichloroethane is 6.26×10^{-4} g/sec.

Step 4 Estimate the PM and metal emissions. The particulate matter emissions will be the sum of PM emissions from mixing and transfer operations. From Equation 4, the mixing emissions are:

$$ER = (0.05)(45,000)(2.78 \times 10^{-4}) = 0.63 \text{ g/sec}$$

From Equation 5, the transfer emissions for PM can be calculated. The mass of material handled is 45,000 kg/hr or 12.5 kg/sec. Assuming default values of 4.4 m/sec for wind speed and 2% for moisture content:

$$ER = \frac{0.00056 \left(\frac{4.4}{2.2} \right)^{1.3} 12.5}{\left(\frac{2}{2} \right)^{1.4}} = 0.0172 \text{ g/sec}$$

The total emission rate for particulate matter is the sum of the two rates:

$$ER_{PM} = 0.63 + 0.017 = 0.65 \text{ g/sec.}$$

The fraction of this value that is lead can be determined using the enrichment factor for lead of 7.34 from Table 3 and Equation 7:

$$X_{lead} = (100)(7.34)(10^{-6}) = 7.34 \times 10^{-4}$$

This fraction can then be used along with the total emission rate in Equation 6:

$$ER_{\text{lead}} = (7.34 \times 10^{-4})(0.65) = 4.8 \times 10^{-4} \text{ g/sec}$$

Step 5 Compare the estimated emission rates from Step 3 and 4 to those from Step 2. The comparison is:

Compound	Equation 1 Emission Rate (g/sec)	Equation 2 Emission Rate (g/sec)
Chloroform	1.24×10^{-4}	1.25×10^{-4}
1,1,1-Trichloroethane	6.20×10^{-4}	6.26×10^{-4}
Lead	1.24	4.8×10^{-4}

The VOC emission rates estimated using Equations 2 and 3 are essentially the same as the total emissions potential for the site. This is expected since the default value used for the percent of the contaminant that is volatilized is 100%.

The estimated emissions of lead are far below the total amount of lead present, which is as expected since far less than 100% of the lead present would be expected to become airborne. The estimated VOC and PM emission rates are used below to assess air impacts.

Step 6 Estimate the downwind ambient air concentrations. From Figure 2, the maximum hourly ambient air concentration at a distance of 400 meters for an in-situ process with a treatment area of 100 m² is approximately 3,000 ug/m³ per g/sec emission rate. This corresponds to an annual average dispersion factor of 240 ug/m³ per g/s ($3,000 \times 0.08 = 240$). Using Equation 8, the hourly average ambient air concentration for chloroform would be:

$$C_m = (1.25 \times 10^{-4})(3000) = 0.38 \text{ ug/m}^3$$

Using Equation 9, the annual average air ambient concentration for chloroform would be:

$$C_a = (0.038)(0.08) = 0.030 \text{ ug/m}^3$$

The ambient air concentrations estimated from Equations 8 and 9 are presented in Table 8.

Step 7 Compare the downwind concentrations to the action level ambient air concentrations. The short-term and long-term action levels from Tables 5, 6, and 7 for the compounds of interest are presented in Table 9. Of the estimated maximum hourly ambient concentrations, only lead is within an order of magnitude of the applicable short-term action levels. The annual average ambient concentrations are below the applicable long-term action levels for the VOCs as is the estimated concentration for lead.

Step 8 Document the results of the air pathway analysis and define a future course of action. Based on these screening level results, a more rigorous analysis of the air impacts is not necessary. The air impacts should be re-examined, however, when site-specific input data are available, if the inputs differ from the default values. Also, it would still be advisable to perform an ambient air monitoring program during the remediation to document actual worker and community exposures.

CONCLUSIONS

The procedures presented here are not intended to negate the need for rigorous analyses that consider site specific meteorological conditions and the health effects of the specific compounds involved. Although the procedures are based on what is typical and reasonable for cleaning up Superfund sites, the underlying assumptions need to be kept in mind. For example, emission models assume typical operating conditions, dispersion models assume Gaussian distribution of the plume and many of the health levels are not endorsed by the Environmental Protection Agency. EPA's Regional Toxicologist should be contacted for general toxicological information and technical guidance on evaluation of chemicals without established toxicity values.

Table 8.

Estimated Emission Rates and Ambient Air Concentrations

	Soil Concentration For Example Problem ($\mu\text{g/g}$)	Emission Rate (g/s)	Ambient Concentrations ($\mu\text{g/m}^3$)	
			Maximum Hourly	Annual Average
Chloroform	0.01	1.25×10^{-4}	0.38	0.030
1,1,1-Trichloroethane	0.05	6.26×10^{-4}	1.9	0.15
Lead	100	4.8×10^{-4}	1.4	0.12

Table 9.

Action Level Concentrations

	Action Levels $\mu\text{g/m}^3$	
	Short-Term	Long-Term
Chloroform	98	0.043 ¹
1,1,1-Trichloroethane	19,000	1,000 ²
Lead	1.5	0.15

¹Based on 10^{-6} , 70-year risk.

²Based on reference dose concentrations (RfCs).

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APPENDIX A

**PHYSICAL PROPERTY DATA
FOR SELECTED ORGANIC COMPOUNDS**
(For compounds in Table 5 of the report)

Source: Reference 4

Appendix A - Physical Property Data

No.	Organic Compound	CAS NO.	Formula	Molecular Weight (g/g-mol)	Vapor Pressure (mm Hg) ^a	Diffusivity in Air (cm ² /sec)	Saturated Vapor Conc. (μg/m ³)	Henry's Law Constant		Maximum Water Solubility (mg/L)	Diffusivity in Water (cm ² /sec)	Log Kow
								H ^b	Log H			
1	Acetaldehyde	75-07-0	C ₂ H ₄ O	44.00	760	0.1240	1.80E+09	9.50e-05	-4.02	inf	1.41e-05	-
2	Acetic acid	64-19-7	C ₂ H ₄ O ₂	60.06	15.41	0.1300	4.97E+07	6.27e-02	-1.20	inf	1.20e-05	-
3	Acetic anhydride	108-24-7	C ₄ H ₆ O ₃	102.09	5.266	0.2350	2.89E+07	5.91e-06	-5.23	-	9.33e-06	-
4	Acetone	67-64-1	C ₃ H ₆ O	58.08	266	0.1240	8.30E+08	2.50e-05	-4.60	inf	1.14e-5	-0.24
5	Acetonitrile	75-05-8	C ₂ H ₃ N	41.06	90	0.1280	1.99E+08	5.80e-06	-5.24	inf	1.66e-5	-0.34
6	Acrolein	107-02-8	C ₃ H ₄ O	56.1	244.2	0.1050	7.36E+08	5.66e-05	-4.25	208,000	1.22e-5	-
7	Acrylic acid	79-10-7	C ₃ H ₄ O ₂	72.1	5.2	0.0908	2.02E+07	1.00e-07	-7.00	inf	1.08e-5	0.13
8	Acrylonitrile	107-13-1	C ₃ H _{3.5} N	53.06	114	0.1220	3.25E+08	8.80e-05	-4.06	73,500	1.34e-5	-0.92
9	Allyl alcohol	107-18-6	C ₃ H ₆ O	58.08	23.3	0.1140	7.27E+07	1.80e-05	-4.74	inf	1.14e-5	-0.22
10	Allyl chloride	107-05-1	C ₃ H ₅ Cl	76.53	368	0.0	1.51E+09	3.71e-01	-0.43	3,600	0.0	-
11	Aniline	62-53-3	C ₆ H ₅ N	93.13	1	0.0700	5.01E+06	2.60e-06	-5.59	35,000	8.3e-6	-
12	Anthracene	120-12-7	C ₁₄ H ₁₀	178.23	1.3E-06	0.0	1.25E+01	6.75e-02	-1.17	1.3	0.0	4.45
13	Benzaldehyde	100-52-7	C ₇ H ₆ O	106.12	1	-	5.70E+06	4.23e-05	-4.37	3,000	-	-
14	Benzene	71-43-2	C ₆ H ₆	78.12	95.2	0.0932	4.00E+08	5.50e-03	-2.26	1,780	9.8e-6	2.12
15	Benzoic acid	65-85-0	C ₇ H ₆ O ₂	122.12	0.00704	0.0	4.62E+04	1.82e-08	-7.74	2,900	7.97e-6	-
16	Benzyl alcohol	100-51-6	C ₇ H ₈ O	108.14	0.15	-	8.72E+05	6.10e-07	-6.21	35,000	-	-
17	Benzyl chloride	100-44-7	C ₇ H ₇ CH ₂ Cl	126.6	1.21	0.0750	8.23E+06	4.33e-04	-3.36	1,619	7.8e-6	2.63
18	Bromoform	75-25-2	CHBr ₃	252.77	5.6	0.0	7.61E+07	5.94e-04	-3.23	3,190	0.0	-
19	1,3-Butadiene	106-99-0	C ₄ H ₆	54.09	2100	0.2490	6.09E+09	1.42e-01	-0.85	735	1.8e-5	1.99
20	N-Butane	106-97-8	C ₄ H ₁₀	58.12	1820	0.2490	5.69E+09	2.91e-01	-0.54	61	-	-
21	2-Butanol	15892-23-6	C ₄ H ₁₀ O	74.12	10	-	3.98E+07	2.20e-06	-5.66	184,000	-	-
22	N-Butanol	71-36-3	C ₄ H ₁₀ O	74.12	6.5	0.0800	2.59E+07	2.20e-06	-5.66	77,000	9.3e-6	-
23	N-Butyl-Acetate	123-86-4	C ₈ H ₁₆ O ₂	116.16	15	0.0	9.37E+07	1.64e-04	-3.79	14,000	0.0	-
24	Tert-Butyl-Alcohol	75-65-0	C ₄ H ₁₀ O	74.12	0.17	-	6.77E+05	2.20e-06	-5.66	inf	-	-
25	Carbon disulfide	75-15-0	CS ₂	76.13	366	0.1040	1.50E+09	1.68e-02	-1.77	2,900	1.0e-5	2.00

Appendix A. (Continued)

No.	Organic Compound	CAS NO.	Formula	Molecular Weight (g/g-mol)	Vapor Pressure (mm Hg)*	Diffusivity in Air (cm ² /sec)	Saturated Vapor Conc. (μg/m ³)*	Henry's Law Constant		Maximum Water Solubility (mg/L)	Diffusivity in Water (cm ² /sec)	Log Kow
								H*	Log H			
26	Carbon tetrachloride	56-23-5	CCl ₄	153.82	113	0.0632	9.34E+08	3.00e-02	-1.52	800	8.8e-6	2.83
27	Carbonyl sulfide	463-58-1	COS	60.1	—	—	—	—	—	—	—	—
28	Catechol	120-80-9	C ₆ H ₄ (OH) ₂	110.1	—	—	—	—	—	—	—	—
29	Chlorine	7782-50-5	Cl ₂	70.9	—	—	—	—	—	—	—	—
30	Chlorobenzene	108-90-7	C ₆ H ₅ Cl	112.56	11.8	0.0730	7.14E+07	3.93e-03	-2.41	488	8.7e-6	2.84*
31	Chlorodifluoromethane	75-45-6	CHClF ₂	86.47	—	—	—	1.00e-01	-1.00	2	—	—
32	Chloroform	67-66-3	CHCl ₃	119.38	208	0.0888	1.33E+09	3.39e-03	-2.47	9,300	1.0e-5	1.97*
33	Chloromethyl methyl ether	107-30-2	C ₂ H ₅ Cl ₂	80.51	—	—	—	9.12x10 ⁻⁶	-5.04	2.5x10 ⁶	—	0.0
34	Chloropentafluoromethane	76-15-3	C ₂ ClF ₅	154.47	—	—	—	2.45e-01	-0.61	—	—	—
35	Chloroprene	126-99-8	C ₄ H ₅ Cl	88.5	273	0.1040	1.12E+09	3.35e-01	-0.475	—	1.0e-5	—
36	M-Cresol	108-39-4	C ₇ H ₈ O	108.14	0.08	0.0740	4.65E+05	4.43e-07	-6.35	25,000	1.0e-5	1.97
37	O-Cresol	95-48-7	C ₇ H ₈ O	108.14	0.24	0.0740	1.40E+06	2.60e-06	-5.59	31,000	8.3e-6	—
38	P-Cresol	106-44-5	C ₇ H ₈ O	108.14	0.11	0.0740	6.39E+05	4.43e-07	-6.35	24,000	1.0e-5	—
39	Cyanogen	460-19-5	C ₂ N ₂	52.04	3980	—	1.11E+10	4.96e-03	-2.30	9,300	—	—
40	Cyclohexane	110-82-7	C ₆ H ₁₂	84.16	100	0.0839	4.52E+08	1.37e-02	-1.86	100	9.1e-6	3.44
41	Cyclohexanol	108-93-0	C ₆ H ₁₂ O	100.16	1.22	0.2140	6.57E+06	4.47e-06	-5.35	38,200	8.31e-6	1.23
42	Cyclohexanone	108-94-1	C ₆ H ₁₀ O	98.14	4.8	0.0784	2.53E+07	4.13e-06	-5.38	23,000	8.62e-6	—
43	Cyclohexene	110-83-8	C ₆ H ₁₀	82.15	—	—	—	1.03e+01	1.01	213	—	2.86
44	Cyclopentane	287-92-3	C ₅ H ₁₀	70.13	317.44	—	1.20E+09	1.00e-02	-2.00	156	—	—
45	Diazomethane	334-88-3	CH ₂ N ₂	42.04	—	—	—	—	—	?	—	—
46	Dibutyl-O-Phthalate	84-74-2	C ₁₆ H ₂₂ O ₄	278.35	1.00E-05	0.0439	—	2.80e-07	-6.55	400	7.8e-6	5.60
47	O-Dichlorobenzene	95-50-1	C ₆ H ₄ Cl ₂	147.00	1	0.0690	7.90E+06	1.94e-03	-2.71	145	7.9e-6	3.60
48	P-Dichlorobenzene	106-46-7	C ₆ H ₄ Cl ₂	147.00	1.2	0.0690	9.48E+06	1.60e-03	-2.80	79	7.9e-6	3.38
49	Dichloroethylether	111-44-4	C ₄ H ₈ Cl ₂ O	143.02	1.4	—	1.08E+07	—	—	?	7.9e-6	3.39
50	Dichlorodifluoromethane	75-71-8	CCl ₂ F ₂	120.91	4870	0.0	3.16E+10	4.01e-01	-0.40	280	0.0	2.16

Appendix A. (Continued)

No.	Organic Compound	CAS NO.	Formula	Molecular Weight (g/g-mol)	Vapor Pressure (mm Hg) ^a	Diffusivity in Air (cm ² /sec)	Saturated Vapor Conc. (μg/m ³) ^b	Henry's Law Constant		Maximum Water Solubility (mg/L)	Diffusivity in Water (cm ² /sec)	Log K _{ow}
								H ^c	Log H			
51	1,1-Dichloroethane	75-34-3	C ₂ H ₄ Cl ₂	98.96	234	0.0919	1.24E+09	1.54E-02	-1.81	5,500	9.9E-6	1.79
52	1,2-Dichloroethane	107-06-2	C ₂ H ₄ Cl ₂	98.96	80	0.1040	4.26E+08	1.20E-03	-2.92	8,690	9.9E-6	1.48
53	1,1-Dichloroethylene	75-35-4	C ₂ H ₃ Cl ₂	96.94	600	0.1040	3.13E+09	2.59E-02	-1.59	210	—	1.84
54	cis-1,2-Dichloroethylene	156-59-2	C ₂ H ₃ Cl ₂	96.94	208	—	1.08E+09	4.55E-03	-2.34	800	—	0.70
55	trans-1,2-Dichloroethylene	156-60-5	C ₂ H ₃ Cl ₂	96.94	324	—	1.69E+09	9.46E-03	-2.02	600	—	0.48
56	Dichloromethane	75-09-2	CH ₂ Cl ₂	84.93	362	0.117	1.65E+09	3.19E-03	-2.50	16,700	1.17 x 10 ⁻⁵	1.30
57	Dichloromono-fluoromethane	75-43-4	CHCl ₂ F	102.92	1360	0.0	7.52E+09	9.21E+02	2.96	0.2	0.0	—
58	1,2-Dichloropropane	78-87-5	C ₃ H ₆ Cl ₂	112.99	42	0.0782	2.55E+08	2.30E-03	-2.64	2,700	8.73E-6	2.00
59	1,3-Dichloropropane	542-75-6	C ₃ H ₆ Cl ₂	110.98	43	0.0	2.57E+08	2.33E-06	-5.63	2,700	0.0	2.00
60	1,2-Dichloro-1,1,2,2-Tetrafluoroethane	76-14-2	C ₂ Cl ₂ F ₄	170.92	—	—	—	2.45E-01	-0.61	137	—	2.82
61	Diethanolamine	111-42-2	C ₄ H ₁₁ NO ₂	105.14	—	—	—	—	—	(61)?	—	—
62	Diethyl amine	109-89-7	C ₄ H ₁₁ N	73.14	350@35C	—	1.38E+09	7.31E-03	-2.14	20,000	—	—
63	N,N-Dimethylaniline	121-69-7	C ₈ H ₁₀ N	121.18	—	—	—	—	—	(63)?	—	—
64	Diethyl ether	60-29-7	C ₄ H ₁₀ O	74.12	440@20C	0.0782	1.75E+09	2.65E-04	-3.58	60,400	8.61E-6	—
65	Dimethylamine	124-40-3	C ₂ H ₇ N	45.08	563 @ 0C	—	1.36E+09	5.24E-06	-5.28	—	—	-0.38
66	Dimethyl formamide	68-12-2	C ₃ H ₇ NO	73.09	4.0	0.0939	1.57E+07	1.92E-05	-4.72	20,000	1.03E-5	—
67	1,1-Dimethyl hydrazine	57-14-7	C ₂ H ₆ N ₂	60.10	157	0.1060	5.07E+08	1.24E-04	-3.91	100,000	1.09E-5	-1.32
68	2,4-Dinitrophenol	51-28-5	C ₆ H ₄ N ₂ O ₃	184.11	53.8	0.0	5.32E+08	1.53E-07	-6.82	19,500	0.0	1.50
69	1,4-Dioxane	123-91-1	C ₆ H ₁₀ O ₂	88.11	37	0.2290	1.75E+08	2.31E-05	-4.64	inf	1.02E-5	0.01
70	Diphenyl	92-52-4	C ₁₂ H ₁₀	154.21	—	—	—	1.01E-01	-1.00	7.5	—	—
71	Epichlorohydrin	106-89-8	C ₃ H ₅ ClO	92.53	17	0.0860	8.45E+07	3.23E-05	-4.49	—	9.08E-6	0.15
72	1,2-Epoxybutane	106-88-7	C ₄ H ₈ O	72.0	—	—	—	—	—	(72)?	—	—
73	Ethanol	64-17-5	C ₂ H ₆ O	46.07	50	0.1230	1.24E+08	3.03E-05	-4.52	inf	1.30E-5	-0.32
74	Ethyl acetate	141-78-6	C ₄ H ₈ O ₂	88.11	100	—	4.74E+08	1.28E-04	-3.89	79,000	—	—
75	Ethyl acrylate	140-88-5	C ₅ H ₈ O ₂	100.12	40	0.0770	2.15E+08	3.50E-04	-3.46	—	—	—

Appendix A. (Continued)

No.	Organic Compound	CAS NO.	Formula	Molecular Weight (g/g-mol)	Vapor Pressure (mm Hg) ^a	Diffusivity in Air (cm ² /sec)	Saturated Vapor Conc. (μg/m ³) ^b	Henry's Law Constant		Maximum Water Solubility (mg/L)	Diffusivity in Water (cm ² /sec)	Log Kow
								H ^c	Log H			
76	Ethyl amine	75-04-7	C ₂ H ₇ N	45.08	1057		2.56E+09	5.24e-06	-5.28	inf	-	-
77	Ethylbenzene	100-41-4	C ₈ H ₁₀	106.16	10	0.0750	5.71E+07	6.44e-03	-2.19	152	7.8e-6	3.15
78	Ethyl Bromide	74-96-4	C ₂ H ₅ Br	108.97	-	-	-	1.00e-02	-2.00	-	-	-
79	Ethyl carbamate	51-79-6	C ₃ H ₇ NO ₂	89.09	10		4.79E+07			(79)?	-	-
80	Ethyl Chloride	75-00-3	C ₂ H ₅ Cl	64.51	1200	0.2710	4.16E+09	1.40e-02	-1.85	5,740	1.15e-5	-
81	Ethylenediamine	107-15-3	C ₂ H ₆ N ₂	60.10	10.7	-	3.46E+07	8.46e-06	-5.07	inf	-	-
82	Ethylene dibromide	106-93-4	C ₂ H ₄ Br ₂	187.88	14	0.0	1.41E+08			inf	0.0	1.76
83	Ethylene glycol	107-21-1	C ₂ H ₆ O ₂	62.07	0.13	0.1080	4.34E+05	1.03e-07	-6.99	inf	1.22e-5	-
84	Ethylene imine	151-56-4	C ₂ H ₅ N	43.07	-	-	-	4.54e-04	-3.34	inf	-	-
85	Ethylene oxide	75-21-8	C ₂ H ₄ O	44.06	1250	0.1040	2.96E+09	1.42e-04	-3.85	-	1.45e-5	-0.22
86	Formaldehyde	50-00-0	CH ₂ O	30.03	3500	0.1780	5.65E+09	5.76e-05	-4.24	550,000	1.98e-5	0.0
87	Formic acid	64-18-6	CH ₂ O ₂	46.03	42	0.0790	1.04E+08	7.00e-07	-6.15	inf	1.37e-6	0.54
88	Furan	110-00-9	C ₄ H ₄ O	68.08	596	0.1040	2.18E+09	5.76e-03	-2.27	10,000	1.22e-5	-
89	Glycerol	56-81-5	C ₃ H ₈ O ₃	92.09	1.60E-04	0.0	7.92E+02	1.94e-08	-7.89	10,000	0.0	-
90	N-Heptane	142-82-5	C ₇ H ₁₆	100.2	46	0.0	2.48E+08	2.02e+00	0.31	3	0.0	-
91	N-Hexane	110-54-3	C ₆ H ₁₄	86.18	150.3	0.2000	6.96E+08	0.122	-0.91	13	7.77e-6	-
92	Hydrazine	302-01-2	H ₂ N ₂	32.05	14.4	-	2.48E+07	6.66e-07	-6.18	-	-	-3.08
93	Hydrochloric acid	7647-01-0	HCl	36.46	32,450		6.36E+10			(93)?	-	-
94	Hydrogen cyanide	74-90-8	CHN	27.03	-	-	-	4.65e-07	-6.33	inf	-	-
95	Hydrogen sulfide	7783-06-4	H ₂ S	34.08	15,200	0.1760	2.78E+10			4,000	-	-
96	Isobutanol	78-83-1	C ₄ H ₁₀ O	74.12	10	0.0860	3.98E+07	2.20e-06	-5.66	95,000	2.20e-6	-
97	Isobutyl acetate	110-19-0	C ₆ H ₁₂ O ₂	116.16	-	-	-	1.64e-04	-3.79	6,300	-	-
98	Isopropyl alcohol	67-63-0	C ₃ H ₈ O	60.1	42.8	0.0980	1.38E+08	1.50e-04	-3.82	inf	1.04e-5	-0.16/0.28
99	Isopropyl amine	75-31-0	C ₃ H ₉ N	59.11	460		1.46E+09	3.58e-04	-3.45	100,000	-	-
100	Isopropylbenzene	98-82-8	C ₉ H ₁₂	120.19	10.9@40C		7.04E+07	6.59e-03	-2.18	50	-	-

Appendix A. (Continued)

No.	Organic Compound	CAS NO.	Formula	Molecular Weight (g/g-mol)	Vapor Pressure (mm Hg)*	Diffusivity in Air (cm ² /sec)	Saturated Vapor Conc. (µg/m ³)*	Henry's Law Constant		Maximum Water Solubility (mg/L)	Diffusivity in Water (cm ² /sec)	Log Kow
								H ^o	Log H			
101	Methanol	67-56-1	CH ₃ O	32.04	114	0.1500	1.96E+08	2.70e-06	-5.57	inf	1.64e-5	-
102	Methyl acetate	79-20-9	C ₃ H ₆ O ₂	74.08	235	0.1040	9.36E+08	1.02e-04	-3.99	194,000	1.00e-5	-
103	Methyl acrylate	96-33-3	C ₅ H ₈ O ₂	86.09	-	-	-	1.44e-07	-6.84	60,000	-	-
104	Methyl amine	74-89-5	CH ₃ N	31.06	770@ -6C	-	1.29E+09	5.38e-03	-2.27	11,500	-	-
105	Methyl bromide	74-83-9	CH ₃ BR	94.94	-	-	-	2.21e-01	-0.66	17,500	-	-
106	Methyl-tert-butyl-ether	1634-04-4	C ₅ H ₁₂ O	88.15	245	0.0806	1.16E+09	5.92e-04	-3.23	48,000	8.026e-6	0.26
107	Methyl chloride	74-87-3	CH ₃ Cl	50.49	3830	0.1260	1.04E+10	8.14e-03	-2.09	6,360	6.5e-6	0.95
108	Methyleyclohexane	108-87-2	C ₇ H ₁₄	98.19	43	-	2.27E+08	9.79e-01	-0.01	14	-	-
109	Methyl-ethyl-ketone	78-93-3	C ₄ H ₈ O	72.11	100	0.0808	3.88E+08	2.16e-04	-3.67	275,000	0.98e-5	1.74±0.12
110	Methyl formate	107-31-3	C ₂ H ₄ O ₂	60.05	500	-	1.61E+09	1.30e-01	-0.89	304	-	-
111	Methyl hydrazine	60-34-4	CH ₆ N ₂	46.07	49.6	-	1.23E+08	3.44e-06	-5.46	inf	-	-
112	Methyl iodide	74-88-4	CH ₃ I	141.94	91	-	-	2.53e-03	-2.60	14,000	-	-
113	Methyl-Isobutyl-Ketone	108-10-1	C ₆ H ₁₂ O	100.16	19.31	0.0750	1.04E+08	4.95e-05	-4.31	19,000	7.08e-6	-
114	Methyl isocyanate	624-83-9	C ₂ H ₃ NO	57.05	348	-	1.07E+09	-	-	**	-	-
115	Methyl-Isopropyl-Ketone	563-80-4	C ₅ H ₁₀ O	86.13	15.7	0.0750	7.27E+07	4.58e-04	-3.34	47,000	0.78e-05	-
116	Methyl mercaptan	74-93-1	CH ₃ S	48.1	-	-	-	4.18e-03	-2.38	23,300	-	-
117	Methyl methacrylate	80-62-6	C ₅ H ₈ O ₂	100.10	39	0.0770	2.10E+08	6.60e-05	-4.18	15,000	8.50e-6	0.79
118	Methyl-N-Propyl-Ketone	107-87-9	C ₅ H ₁₀ O	86.13	-	-	-	4.58e-04	-3.34	-	-	-
119	Alpha-Methyl-Styrene	98-83-9	C ₉ H ₁₀	118.18	0.076	0.2640	4.83E+05	5.91e-03	-2.23	2	-	-
120	Monoethanolamine	141-43-5	C ₂ H ₇ NO	61.08	-	-	-	3.22e-07	-6.49	100,000	-	-
121	Morpholine	110-91-8	C ₄ H ₉ NO	87.12	10.08	0.0910	4.72E+07	5.73e-05	-4.24	inf	9.60e-6	-1.08
122	Naphthalene	91-20-3	C ₁₀ H ₈	128.19	0.023	0.0590	1.58E+05	4.80e-04	-3.32	30	7.50e-6	3.01/3.45
123	2-Nitropropane	79-46-9	C ₃ H ₇ NO ₂	89.09	12.9	-	6.18E+07	2.23e-04	-3.65	100,000	-	-
124	N-Nitrosodimethylamine	62-75-9	C ₂ H ₆ N ₂ O	74.08	-	-	-	3.0x10 ⁻⁶	-7.52	1.2x10 ⁷	-	-
125	N-Nitrosomorpholine	59-89-2	C ₄ H ₈ N ₂ O ₂	116.11	-	0.0590	-	-	-	0.059	1.00e-5	-

Appendix A. (Continued)

No.	Organic Compound	CAS NO.	Formula	Molecular Weight (g/g-mol)	Vapor Pressure (mm Hg) ^a	Diffusivity in Air (cm ² /sec)	Saturated Vapor Conc. (μg/m ³) ^a	Henry's Law Constant		Maximum Water Solubility (mg/L)	Diffusivity in Water (cm ² /sec)	Log Kow
								H ^b	Log H			
126	N-Nonane	111-84-2	C ₉ H ₂₀	128.26	4.28		2.95E+07	4.48E-01	-0.35	79	-	-
127	N-Octane	111-65-9	C ₈ H ₁₈	114.23	17	0.0	1.04E+08	3.87E+00	0.59	20	0.0	-
128	N-Pentane	109-66-0	C ₅ H ₁₂	72.15	513		1.99E+09	1.22E-01	-0.91	360	-	-
129	Phenanthrene	85-01-8	C ₁₄ H ₁₀	178.23	2.00E-04	0.0	1.92E+03	6.05E-03	-2.22	0.82	0.0	4.46
130	Phenol	108-95-2	C ₆ H ₆ O	94.11	0.0341	0.0820	1.72E+05	4.54E-07	-6.34	80,000	9.10E-6	1.46
131	Phosgene	75-44-5	CCl ₂ O	98.92	1,394	0.1080	7.41E+09	1.71E-01	-0.767	slightly	1.12E-6	-
132	Phosphine	7803-51-2	H ₃ P	34.00	2,000	-	3.66E+09			6,200	-	-
133	Phthalic anhydride	85-44-9	C ₈ H ₄ O ₃	148.11	0.0015	0.0710	1.19E+04	9.00E-07	-6.05	153,000	8.60E-6	-
134	Propane	74-98-6	C ₃ H ₈	44.1	7600	-	1.80E+09	2.20E-02	-1.66	2,000	-	2.36
135	1,2-Propanediol	57-55-6	C ₃ H ₈ O ₂	76.11	0.3		-	1.50E-06	-5.82	20,000	-	-
136	1-Propanol	71-23-8	C ₃ H ₈ O	60.1	20.85		6.74E+07	1.50E-04	-3.82	inf	-	-
137	beta-Propiolactone	57-57-8	C ₃ H ₄ O ₂	72.06	3.4	-	1.32E+07			350,000	-	-
138	Propionaldehyde	123-38-7	C ₃ H ₆ O	58.08	300	0.102	9.37E+08	1.15E-06	-5.94	200,000	1.14E-5	-
139	Propionic acid	79-09-4	C ₃ H ₆ O ₂	74.08	10	-	3.98E+07	4.87E-05	-4.31	inf	-	-
140	N-Propyl-Acetate	109-60-4	C ₇ H ₁₄ O ₂	102.12	35	0.0	1.92E+08	2.94E-04	-3.53	20,400	0.0	-
141	Propylene oxide	75-56-9	C ₃ H ₆ O	58.08	524.5	0.1040	1.64E+09	1.34E-03	-2.87	30,000	1.00E-5	-
142	1,2-Propylenimine	75-55-8	C ₃ H ₇ N	54.1	112		3.26E+08			(142)?	-	-0.48
143	Pyridine	110-86-1	C ₅ H ₅ N	79.1	20	0.0910	8.50E+07	2.36E-05	-4.63	inf	8.10E-6	0.66
144	Quinone	106-51-4	C ₆ H ₄ O ₂	108.09	-		-			(144)?	-	-
145	Styrene	100-42-5	C ₈ H ₈	104.15	7.3	0.0710	4.09E+07	2.61E-03	-2.58	300	8.00E-6	2.95
146	1,1,1,2-Tetrachloro-2,2-Difluoroethane	76-11-9	C ₂ Cl ₄ F ₂	203.83	-		-	2.45E-01	-0.61	-	-	-
147	1,1,2,2-Tetrachloroethane	79-34-5	C ₂ H ₂ Cl ₄	167.85	6.5	0.0710	5.86E+07	2.50E-04	-3.60	2,900	7.90E-6	2.39
148	Tetrachloroethylene	127-18-4	C ₂ Cl ₄	165.83	19	0.0720	1.69E+08	2.90E-02	-1.54	150	8.2E-6	2.60*
149	Tetrahydrofuran	109-99-9	C ₄ H ₈ O	72.11	72.1	0.0980	2.79E+08	4.90E-05	-4.31	inf	1.05E-5	-
150	Toluene	108-88-3	C ₇ H ₈	92.14	30	0.0870	1.49E+08	6.68E-03	-2.18	515	8.60E-6	2.73

Appendix A. (Continued)

No.	Organic Compound	CAS NO.	Formula	Molecular Weight (g/mol)	Vapor Pressure (mm Hg)*	Diffusivity in Air (cm ² /sec)	Saturated Vapor Conc. (μg/m ³)*	Henry's Law Constant		Maximum Water Solubility (mg/L)	Diffusivity in Water (cm ² /sec)	Log Kow
								H [†]	Log H			
151	P-Toluidine	106-49-0	C ₇ H ₉ N	107.16	0.3	—	1.73E+06	1.91e-05	-4.72	7,400	—	—
152	1,1,1-Trichloroethane	71-55-6	C ₂ H ₃ Cl ₃	133.41	123	0.0780	8.82E+08	1.74e-02	-1.76	4,400	8.8e-6	2.5
153	1,1,2-Trichloroethane	79-00-5	C ₂ H ₃ Cl ₃	133.41	25	0.0792	1.79E+08	7.40e-04	-3.13	4,500	8.80e-6	2.47
154	Trichloroethylene	79-01-6	C ₂ HCl ₃	131.4	75	0.0790	5.30E+08	9.10e-03	-2.04	1,100	9.10e-6	2.38
155	Trichlorofluoromethane	75-69-4	CCl ₃ F	137.37	667	0.0870	4.92E+09	5.83e-02	-1.23	1,100	9.70e-6	2.53
156	1,2,3-Trichloropropane	96-18-4	C ₃ H ₃ Cl ₃	147.43	3.1	0.0710	2.46E+07	2.80e-02	-1.55	—	7.90e-6	—
157	1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	C ₂ Cl ₃ F ₃	187.38	300	0.0780	3.02E+09	2.45e-01	-0.61	170	8.20e-6	2.00
158	Triethylamine	121-44-8	C ₆ H ₁₅ N	101.19	400	—	2.18E+09	2.66e-03	-2.58	20,000	—	—
159	Trifluorobromomethane	75-63-8	CBR ₃ F ₃	148.91	—	—	—	1.00e-01	-1.00	—	—	—
160	1,2,3-Trimethylbenzene	526-73-8	C ₉ H ₁₂	120.19	—	—	—	1.47e-01	-0.83	—	—	—
161	1,2,4-Trimethylbenzene	95-63-6	C ₉ H ₁₂	120.19	—	—	—	1.47e-01	-0.83	57	—	—
162	1,3,5-Trimethylbenzene	108-67-8	C ₉ H ₁₂	120.19	1.86	—	1.20E+07	1.47e-01	-0.83	20	—	—
163	Vinyl Acetate	108-05-4	C ₄ H ₆ O ₂	86.09	115	0.0850	5.32E+08	6.20e-04	-3.21	20,000	9.20e-6	—
164	Vinyl bromide	593-60-2	C ₂ H ₃ Br	107.0	895	—	5.15E+09	—	—	(164)?	—	—
165	Vinyl-Chloride	75-01-4	C ₂ H ₃ Cl	62.5	2660	0.0900	8.94E+09	8.60e-02	-1.07	1.1	1.04e-5	1.38
166	M-Xylene	108-38-3	C ₈ H ₁₀	106.2	8	0.0700	4.57E+07	5.20e-03	-2.28	200	7.80e-6	3.26
167	O-Xylene	95-47-6	C ₈ H ₁₀	106.2	7	0.0870	4.00E+07	5.27e-03	-2.28	175	1.00e-5	2.95
168	P-Xylene	106-42-3	C ₈ H ₁₀	106.2	9.5	0.0	5.42E+07	5.27e-03	-2.28	198	0.0	3.15

*At 25°C

$$H \left(\frac{\text{atm} \cdot \text{m}^3}{\text{g} \cdot \text{mol}} \right)$$

APPENDIX B

PHYSICAL PROPERTY DATA
FOR SELECTED SEMI-VOLATILE ORGANIC COMPOUNDS
(For compounds in Table 6 of the report)

Appendix B - Physical Property Data For Selected Semi-Volatile Organic Compounds

No.	Organic Compound	CAS No.	Formula	Molecular Weight (g/g-mol)	Vapor Pressure (mm Hg)*	Diffusivity in Air (cm ² /sec)	Saturated Vapor Conc (ug/m ³)*	Henry's Law Constant		Max H ₂ O Solubility (mg/L)	Diffusivity in H ₂ O (cm ² /sec)	Log K _{ow}
								H ^b	Log H			
1	Acenaphthene	83-32-9	C12H10	154.21	0.005	0.0	4.15e+04	7.71e-08	-7.11	2	0.0	
2	2-Acetoaminofluorene	53-96-3	C15H13NO	223.26	0.017		2.01e+05	2.65e-08	-7.58	6.5		3.28
3	2-Acetylfuran	1192-62-7	C6H6O2	110.11		0.0		1.10e-04	-3.96	100	0.0	
4	Benzidine	92-87-5	C12H12N2	184.24		0.0298		3.66e-07	-6.44	400		1.55
5	Benzo(a)anthracene	56-55-3	C18H12	228.30	1.50e-07	0.051	1.84e+00	1.38e-09	-8.86	0.012	9.00e-08	5.23
6	Benzo(a)pyrene	50-32-8	C20H12	252.32	0.000568	0.043	7.71e+03	1.38e-09	-8.86	0.003	9.00e-08	6.16
7	Benzo(b)fluoranthene	205-99-2	C20H12	252.32	1626	0.044	2.21e+10	2.01e-05	-4.70	0.0011	4.70e-06	6.33
8	Benzo(g,h,i)perylene	191-24-2	C22H12	276.34								
9	Benzo(k)fluoranthene	207-08-9	C20H12	252.32	3.84e-04	0.044	5.21e+03	1.06e-07	-6.98	0.0006	4.70e-06	6.46
10	Bis(2-ethylhexyl)phthalate	117-81-7	C24H38O4	390.56	2.53e-03		5.31e+04	1.38e-07	-6.86	0.35		5.61
11	Chlordane	57-74-9	C10H6Cl8	410.00	1.00e-05	0.0	2.20e+02	3.67e-05	-4.44	0.93	0.0	5.58
12	Chrysene	218-01-9	C18H12	228.30	5.76e-10	0.046	7.07e-03	1.18e-09	-8.93	0.0017	5.00e-06	4.96
13	Cresol	1319-77-3	C7H8O	108.15	0.3		1.74e+06	2.13e-05	-4.67	2000		1.95
14	Dioxin (2,3,7,8-TCDD)	1746-01-6	C12H4Cl4O2	321.96	1.94e-04		3.36e+03	4.44e-05	-4.35	1.68e-04		6.37
15	Dibenzofuran	132-64-9	C12H8O	168.21								
16	Dibenzo(a,h)anthracene	53-70-3	C22H14	278.36	5.20e-11	0.042	7.78e-04	3.81e-08	-7.42	0.0015	4.50e-06	6.85
17	Di-n-butylphthalate	84-74-2	C16H22O4	278.35	1.00e-05	0.0439	1.50e+02	2.80e-07	-6.55	400	7.80e-06	5.60
18	Ethylenamine	593-67-9										
19	Fluoranthene	206-44-0	C16H10	202.26	0.0177	0.049	1.93e+05	6.73e-02	-1.17	0.3	5.30e-06	5.00
20	Fluorene	86-73-7	C13H10	166.23	1.63e-05	0.055	1.46e+02	1.78e-08	-7.75	2	5.70e-06	4.12
21	Heptachlor	76-44-8	C10H5Cl7	373.32	0.0008	0.0	1.61e+04	2.30e-08	-7.64	0.056	0.0	5.19
22	Hexachlorocyclopentadiene	77-47-4	C5Cl6	272.77	0.081	0.0561	1.19e+06	1.60e-02	-1.80		6.16e-08	
23	Indeno(1,2,3-CD)pyrene	193-39-5	C22H12	276.34	7.60e-08	0.044	1.13e+00	5.07e-13	-12.29	0.00017	4.50e-06	7.09
24	Lindane	58-89-9	C6H6Cl6	290.83	9.40e-06		1.47e+02	3.16e-06	-5.50	12.4		3.71
25	Maleic anhydride	108-31-6	C4H2O3	98.06	0.0001	0.095	5.27e+02	4.00e-08	-7.40	788	1.11e-05	
26	2-Methylnaphthalene	91-57-6	C11H10	142.20	0.054	0.0	4.15e+05	5.80e-05	-4.24	26		

Appendix B - (Continued)

No.	Organic Compound	CAS No.	Formula	Molecular Weight (g/g-mol)	Vapor Pressure (mm Hg)*	Diffusivity in Air (cm ² /sec)	Saturated Vapor Conc (ug/m ³)*	Henry's Law Constant		Max H ₂ O Solubility (mg/L)	Diffusivity in H ₂ O (cm ² /sec)	Log K _{ow}
								H*	Log H			
27	p-Nitrosodiphenylamine	156-10-5	C ₁₂ H ₁₀ N ₂ O	198.23								
28	Nitrobenzene	98-95-3	C ₆ H ₅ NO ₂	123.11	0.3	0.076	1.99e+06	1.13e-05	-4.95	1950	8.60e-08	1.91
29	PCBs	1336-36-3		328.00	1.42	0.104	2.51e+07	2.94e-04	-3.53	0.0077	1.00e-05	9.21
30	PAHs	61-78-9	C ₉ H ₁₀ N ₂ O ₃	194.19								
31	Parathion	56-38-2	C ₁₀ H ₁₄ NO ₅ PS	291.27	0.003	0.0	4.70e+04	4.80e-05	-4.32	19	0.0	3.38
32	Pyrene	129-00-0	C ₁₆ H ₁₀	202.26	9.74e-04	0.051	1.06e+04	7.00e-09	-8.15	2	5.50e-06	4.88
33	Tridecane	629-50-5	C ₁₃ H ₂₈	184.37	1.55e-09		1.54e-02					
34	Undecane	1120-21-4	C ₁₁ H ₂₃	156.32	1.20e-08		1.01e-01	1.83e+00	0.26			

* At 25°C

$$H \left(\frac{\text{atm} \cdot \text{m}^3}{\text{g} \cdot \text{mol}} \right)$$