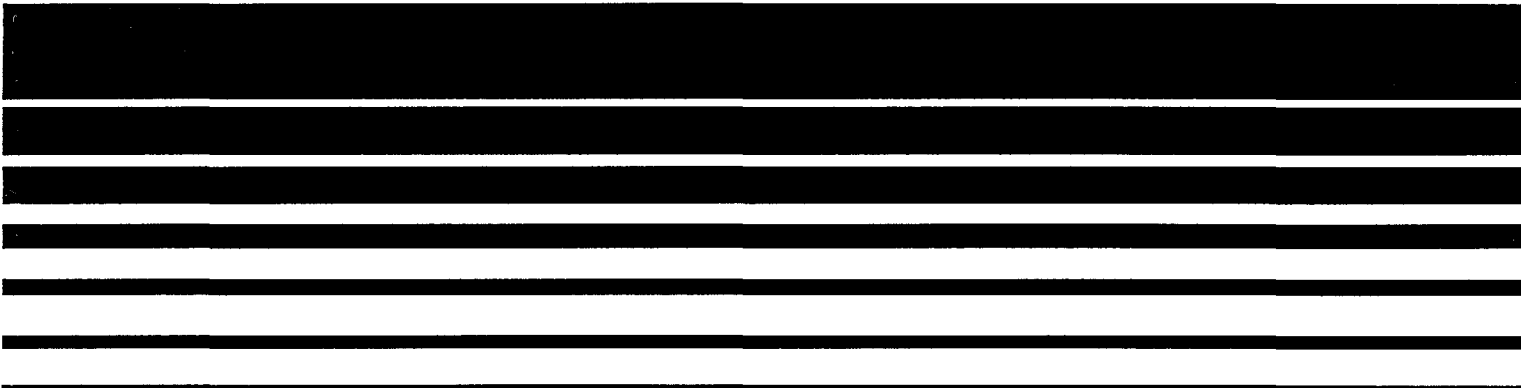




AIR/SUPERFUND NATIONAL TECHNICAL GUIDANCE STUDY SERIES

ESTIMATION OF AIR IMPACTS FROM AREA SOURCES OF PARTICULATE MATTER EMISSIONS AT SUPERFUND SITES



**ESTIMATION OF AIR IMPACTS FROM AREA
SOURCES OF PARTICULATE MATTER EMISSIONS
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 emissions of particulate matter (PM) from soils handling operations at Superfund sites. These procedures are analogous to procedures for air strippers, soil vapor extraction systems, and excavation that have previously been published.^{1,2,3} Materials handling operations are necessary at any site where ex-situ treatment is performed. In addition, soils handling operations, such as excavation or grading, are frequently performed as part of site preparation. Procedures are given to evaluate the effect of handling 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

Materials handling covers such activities as excavation, dumping, grading, short-term storage, and sizing and feeding soil or waste into treatment processes. Information on equipment and operating practices for material handling operations are available.^{4,5}

Excavation and removal of contaminated soils and sludges is a common practice at Superfund sites. Excavation and removal may be the selected remediation approach or it may be a necessary step in a remediation approach involving treatment. If removal is the preferred approach, the excavated soil typically is transported off-site for subsequent disposal at a landfill. If the soil contains large amounts of fuel or highly toxic contaminants, the soil may need to be treated off-site prior to final disposal. Excavation activities are also typically part of on-site treatment processes such as incineration, thermal desorption, batch biotreatment, landtreatment, and certain chemical and physical treatment methods. The soil is excavated and transported to the process unit and the treated soil typically is put back into place on the site.

Since digging soil and immediately transferring it directly to transport vehicles or treatment systems is rarely feasible or efficient, soil will be handled several times. In most cases, soil will be excavated and placed into a temporary holding area and then handled one to two more times on-site. Each handling step may involve dumping the material. If ex-situ treatment is performed, the contaminated material usually will need to be sized and fed into the treatment unit. Elevated levels of PM (and VOC) emissions are possible each time the soil is handled.

Site preparation activities often involve some amount of excavation, grading, etc. to construct roadways and prepare areas for office trailers and other support equipment. While site preparation tends to be limited to non-contaminated areas, PM emissions are still likely to occur and some tracking of contaminated material into clean areas may inadvertently take place.

The rate of materials handling operations at Superfund sites tend to be controlled by factors such as safety concerns, storage capacity or treatment capacity, rather than being limited by the operational capacities of the equipment that is used. For these reasons, actual materials handling rates tend to be far below typical handling rates at construction sites.⁴

Multiple potential emission points exist for each of the various soils handling operations. For excavation, the main emission points of concern are emissions from:

- Exposed waste in the excavation pit;
- Material as it is dumped from the excavation bucket; and
- Waste/soil in short-term storage piles.

In addition, emissions of particulate matter, VOC, nitrogen oxides, etc. will also occur from the engines of the earth-moving equipment. While these emissions will not require any additional control devices (beyond those provided by the manufacturer), the equipment emissions should be considered when evaluating any air monitoring data.

Particulate matter (PM) emissions will depend primarily on the particle size distribution of the soil, its moisture content, the wind speed, and the operating practices that are followed. The longer or more energetic the moving and handling, the greater likelihood that PM emissions will occur. The magnitude of emissions from soils handling operations will vary with the operating conditions. Add-on control technologies are available for minimizing PM emissions, but they are relatively ineffective and costly to implement. Control of emissions can also be achieved by controlling the operating conditions within preset parameters. The rate of excavation and dumping, the drop height, the amount of exposed surface area, the length of time that the soil is exposed, the shape of the storage piles, and the dryness of the surface soil layers will all influence the levels of PM emissions. Large reductions in emissions can be achieved by identifying and operating within acceptable ranges of operating conditions.

A number of methods are available for controlling particulate matter emissions from soils. In general, any method designed primarily for particulate control will also reduce VOC emissions and vice versa. Compared to point source controls, emission controls for excavation and other area sources are difficult to implement and only moderately effective. Controls such as water sprays or foams will alter the percent moisture, bulk density, and average heating value of the soil and may affect treatment and disposal options. Emission controls for soil area sources include:⁶

- Covers and physical barriers;
- Temporary and long-term foam covers;
- Water sprays;
- Water sprays with additives;
- Operational controls;
- Complete enclosures;
- Wind screens; and
- Collection hoods.

ESTIMATION OF PARTICULATE MATTER AIR EMISSIONS

Simple air emission estimation procedures are presented in this section for area sources of particulate matter (PM) and metals, including: materials handling and other area sources such as storage piles and dry surface impoundments. Soils handling is a very common source of particulate matter emissions at Superfund sites; excavation of soils, soil transport, dumping and formation of soil storage piles, and grading are all routinely performed. The PM emissions arising from these operations should be evaluated, whether the material is contaminated or not since PM emissions (less than 10 microns in diameter) are a criteria pollutant. Few emissions models for PM from materials handling exist. A comprehensive collection of empirically based screening models developed by Cowherd et al.⁷ was used as the principal source of all models in this document.

The emissions of PM from all transfer operations - adding to or removing from piles, conveyor belts, truck dumping - are expressed in Equation 1:

(Eq. 1)

$$E = \frac{k (0.0016)(M) \left(\frac{U}{2.2} \right)^{1.3}}{\left(\frac{X_{H_2O}}{2} \right)^{1.4}}$$

where E = PM emissions [g];
k = particle size multiplier [unitless];
0.0016 = empirical constant [g/Kg]; and
M = mass of waste handled [Kg];
U = mean wind speed [m/sec];
2.2 = empirical constant [m/sec]; and
X_{H₂O} = percent moisture content [%].

Reference 8 provides a more detailed equation for this same activity that takes into account the drop height, the silt content of the material, and the capacity of the dump bucket. The particle size multiplier, k, for several sizes of particles for use with Equation 1 are:

size (microns)	multiplier, k
< 50	1.0
< 30	0.74
< 15	0.48
< 10	0.35
< 5	0.20
< 2.5	0.11

For emissions from the erosion of intermittently active piles, use erosion Equation 9 for each period between activity; use the above equation during the activity itself.

For emissions during materials handling involving mixing and tilling (waste incorporation and cultivation), a simple model is:

$$E = k (0.00538) SA 10^{-4} (s)^{0.6} \quad (\text{Eq. 2})$$

where E = PM emissions [g];
k = particle size multiplier (0.21 for PM₁₀) [unitless];
0.00538 = empirical constant [g/hectare];
10⁻⁴ = conversion factor [hectare/m²];
SA = area treated [m²]; and
s = percent silt content [%].

Particle size multipliers for size fractions other than PM_{10} are not available for Equation 2. If wastes or soil are being graded by a bulldozer or any other tractor with a blade, then the following equation should be used to predict the PM_{10} (particulate matter of less than 10 microns) emissions:

$$ER = \frac{0.094 s^{1.5}}{X_{H_2O}^{1.4}} \quad (\text{Eq. 3})$$

where ER = PM_{10} emission rate [g/sec];
 0.094 = empirical constant [g/sec];
 s = percent silt content [%]; and
 X_{H_2O} = percent moisture content [%].

The emission rate of traffic on paved roads in grams per vehicle kilometers traveled (VKT) is given by Equation 4.

$$EF = 220 \left(\frac{sL}{12} \right)^{0.3} \quad (\text{Eq. 4})$$

where EF = PM_{10} emission factor [g/VKT];
 220 = empirical constant [g/VKT];
 sL = silt surface loading [g/m²];
 12 = empirical constant [g/m²]; and
 0.3 = empirical constant [unitless].

For unpaved roads, the PM_{10} emission model is given by Equation 5:

$$EF = 610 \left(\frac{s}{12} \right) \left(\frac{S}{48} \right) \left(\frac{W}{2.7} \right)^{0.7} \left(\frac{w}{4} \right)^{0.5} \frac{(365 - p)}{365} \quad (\text{Eq. 5})$$

where EF = PM_{10} emission factor [g/VKT];
 610 = empirical constant [g/VKT];
 s = percent silt content of road surface [%];
 12 = empirical constant [unitless];
 S = mean vehicle speed [km/hr];
 48 = empirical constant [km/hr];
 W = mean vehicle weight [Mg];
 2.7 = empirical constant [Mg];
 w = mean number of wheels per vehicle [unitless];
 4 = empirical constant [unitless];
 365 = no. of days per year [days]; and
 p = number of days with < 0.01 inches precipitation [days].

The emission factors can be converted into a total mass emitted if multiplied by the number of vehicle kilometers traveled.

If the dust is contaminated, the PM or PM₁₀ emission rates given in this document may be translated to emission rates of the contaminant as follows:

$$EF_i = X_i EF \quad (\text{Eq. 6})$$

where EF_i = emission factor of contaminant i [g/VKT]; 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 metals.⁹ 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 [$\text{g}/\mu\text{g}$].

Fugitive dust may be released from a variety of origins other than materials handling. A remediation activity that may be a significant area sources of fugitive dust is solidification/stabilization. Non-remediation sources include storage piles and dry impoundments.

Equations based on fundamental physical laws have been reported for windblown dust^{10,11}, but the most widely accepted equations are those empirically derived by Cowherd, et al.^{8,12,13}. The most suitable equations for inclusion in this manual are those given by Cowherd, et al.⁷ for open waste piles and staging areas, dry surface impoundments, and waste stabilization. These are incorporated in the manual along with the metal enrichment factors for dust presented in Volume III of the National Technical Guidance Series (NTGS) documents.⁹

A simple model of erosion from level areas such as dry surface impoundments during a time period t between disturbances is given by:

(Eq. 8)

$$ER = \frac{k SA p_t}{t 86,400}$$

where ER = PM emission rate from surface material during period t [g/sec];
 k = particle size multiplier [unitless];
 SA = area of contamination [m²];
 p_t = erosion potential corresponding to fastest mile of wind during period t [g/m²];
 t = no. of days between disturbances [day]; and
 86,400 = conversion factor [sec/day].

Particle size multipliers for Equation 8 are:

Size (microns)	Multiplier, k
< 30	1.0
< 15	0.6
< 10	0.5
< 2.5	0.2

Total suspended particulates (TSP) from wind erosion of continuously active piles can be estimated as:

(Eq. 9)

$$EF = 1.9 \left(\frac{s}{15} \right) \frac{(365 - p)}{235} \left(\frac{f}{15} \right)$$

where EF = PM emission factor (g/m²-day);
 0.19 = empirical constant (g/m²-day);
 s = percentage silt of aggregate (%);
 1500 = empirical constant (unitless);
 365 = no. of days/year (days);
 p = number of days of precipitation > 0.01 inch per year (days);
 235 = empirical constant (days);
 f = fraction of time wind > 5.4 m/sec at mean pile height (unitless); and
 15 = empirical constant (unitless).

The fraction of TSP that is PM₁₀ can be assumed to be 50%. Equation 9 is valid for piles that are active at least once per day.

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

(Eq. 10)

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

where E = PM 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 [%].

For all the equations given above, 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 particulate matter emissions. The minimum field data required to estimate emissions for the various sources covered in this document are:

- Transfer operations: percent moisture content of the material;
- Mixing and tilling: area treated and silt content of soil;
- Grading: percent moisture content and silt content of material;
- Traffic on paved roads: silt surface loading;
- Traffic on unpaved roads: silt content of road surface;
- Metal emissions for any operation: average concentration of metal in bulk soil;
- Dry surface impoundments: surface area of contamination and the number of days between disturbances;
- Continuously active piles: percentage silt of aggregate and the fraction of time with high winds; and
- Stabilization and solidification: percent moisture content and mass of material handled.

Aerodynamic particle size multipliers for Equations 1, 2, and 8 are provided above. In general, meteorological data will be available from an on-site monitoring station. If not,

meteorological data may be obtained from a local airport or government monitoring station. Soil data is available from the state agricultural service or the federal Soil Conservation Service.

Default values for equation input parameters are provided in Table 1. Some input variables, such as mass of material handled and surface area graded, are extremely site- and operation-specific, so no default values for these variables are given. Table 2 contains default values for metal enrichment of soils for use in Equation 7. Figure 1 shows a geographic map of areas of the U.S. and the average number of days with >0.01 inch of precipitation annually.

Procedures for calculating the erosion potential are given in Reference 7. Table 3 provides default values for the input parameters needed for Equations 8 and 9. For Equation 10, the fraction of TSP made up of PM_{10} is estimated to be 0.5.

These emission models assume that after a disturbance, only a certain fraction of the soil's surface will erode, regardless of the time exposed. That is why Equation 8 does not depend on time, except for the length of the period between disturbances. Equation 9 is for continuously active disturbances, and so it assumes that at any point in time, a disturbance has just occurred, and the same fraction is able to erode. For in-place contaminated soil, over-prediction of the emissions is possible as a soil crust tends to form, reducing the erodibility of the pile or field.

These models are equally applicable to a wide variety of materials handling activities. They are based on the premise that a certain percentage of a soil's surface area has a high "erosion potential", and that the rest of the surface will not be emitted. 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 high silt content of soil, 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.

Table 1.

Default Values for Estimating Emissions from Materials Handling

Parameter	Symbol	Units	Default Value	Expected Range	Reference
Mean wind speed	U	m/sec	4.4	0 - 4.47	*
Moisture content	X _{H2O}	%	10	—	*
Silt content	s	%	8 (<75 µm)	2 - 20	7
Silt surface loading	sL	g/m ²	5	0.3 - 30	7
Mean vehicle speed	S	km/hr	20	8 - 45	7
Mean vehicle weight	W	Mg	3 (plant vehicle)	2 - 9	7
			20 (Commercial haulers)	9 - 45	7
			30 (plant haul trucks)	20 - 50	7
Mean # of wheels	w	unitless	10	4 - 18	7

* = Author's estimate.

Table 2.

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 9

*CAAA = Clean Air Act Amendments of 1990

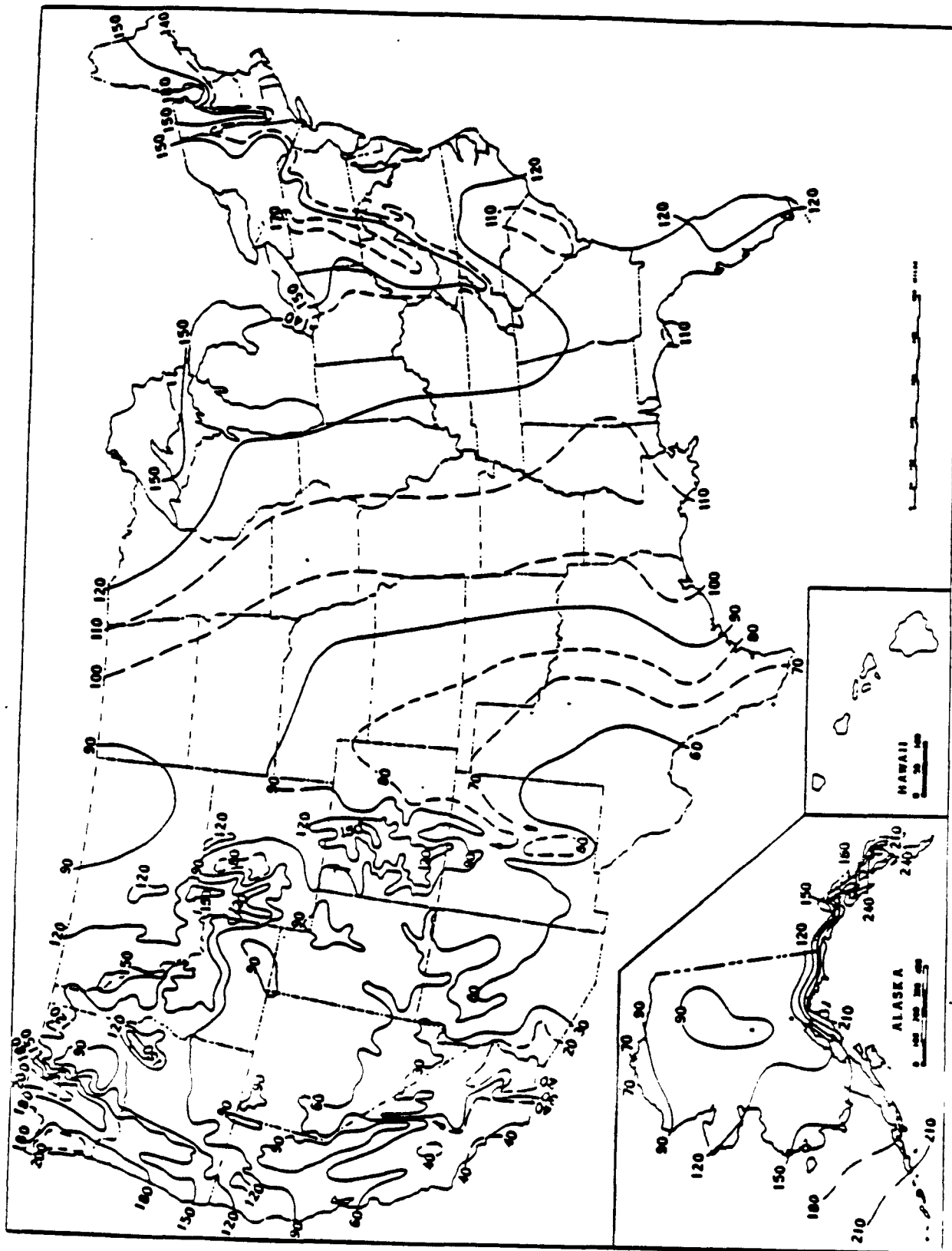


Figure 1.. Mean Annual Number of Days with at Least 0.01 Inches of Precipitation.

Table 3.

Default Values for Estimating PM Emissions from Other Area Sources

Parameter	Symbol	Units	Default Value	Expected Range	Reference
Surface area	SA	m ²	2000	Site specific	--
Erosion potential	P _i	g/m ²	33	0 - 525	7
Percentage of silt	s	%	2.2	0.44 - 19	7
Fraction of time with high winds	f	unitless	20	Site specific	--
Wind speed	U	m/sec	4.4	0.6 - 6.7	7
Moisture fraction	X _{H2O}	%	2	0.25 - 4.8	7

¹Moisture content of stabilized material.

Note: For use with Equations 8, 9, and 10.

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 model.¹⁴ 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 remediation scenarios for area sources of PM or PM₁₀ emissions. The scenarios were developed based on experience and scientific judgment. The traffic scenario assumes back and forth traffic in a confined area on-site; therefore, emissions should be modeled as an area source rather than a line source. 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 source. The curves were calculated according to the following assumptions: 1) the emission rate is 1 gram per second; 2) a flat terrain without any structures near the emission source; and 3) the emission plume is of low, positive buoyancy; 4) the emissions are uniformly distributed over the emitting area and constant over time; and 5) the receptors are at ground level. A release height of 2m was used for dumping/active piles, all other sources were assumed to be 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 multiple sources are present, each should be evaluated separately (i.e., the downwind concentration due to each source should be calculated and these values summed to get the total concentration at a given location). If a given source is larger than the example scenario, the appropriate curve in Figure 2 may still be used. The dispersion factor, in micrograms/m³ per g/sec, obtained from Figure 2 can be used in Equation 11 to estimate the maximum hourly ambient concentration and into Equation 12 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 12 is used to convert the short-term estimate to an annual average estimate.

Table 4.

Example Scenarios for Area Sources of PM Emissions

Parameter	Units	Scenario
<u>Dumping, Active Piles</u>		
Dimensions	m	10 x 10 x 2
Area	m ²	100
Release height	m	2
<u>Mixing, Tilling, Grading, Waste Transfer</u>		
Dimensions	m	50 x 50
Area	m ²	2500
Release Height	m	0
<u>Dry Surface Impoundments</u>		
Dimensions	m	100 x 100
Area	m ²	10,000
Release Height	m	0
<u>Traffic</u>		
Dimensions	m	50 x 50
Area	m ²	2500
Release Height	m	0

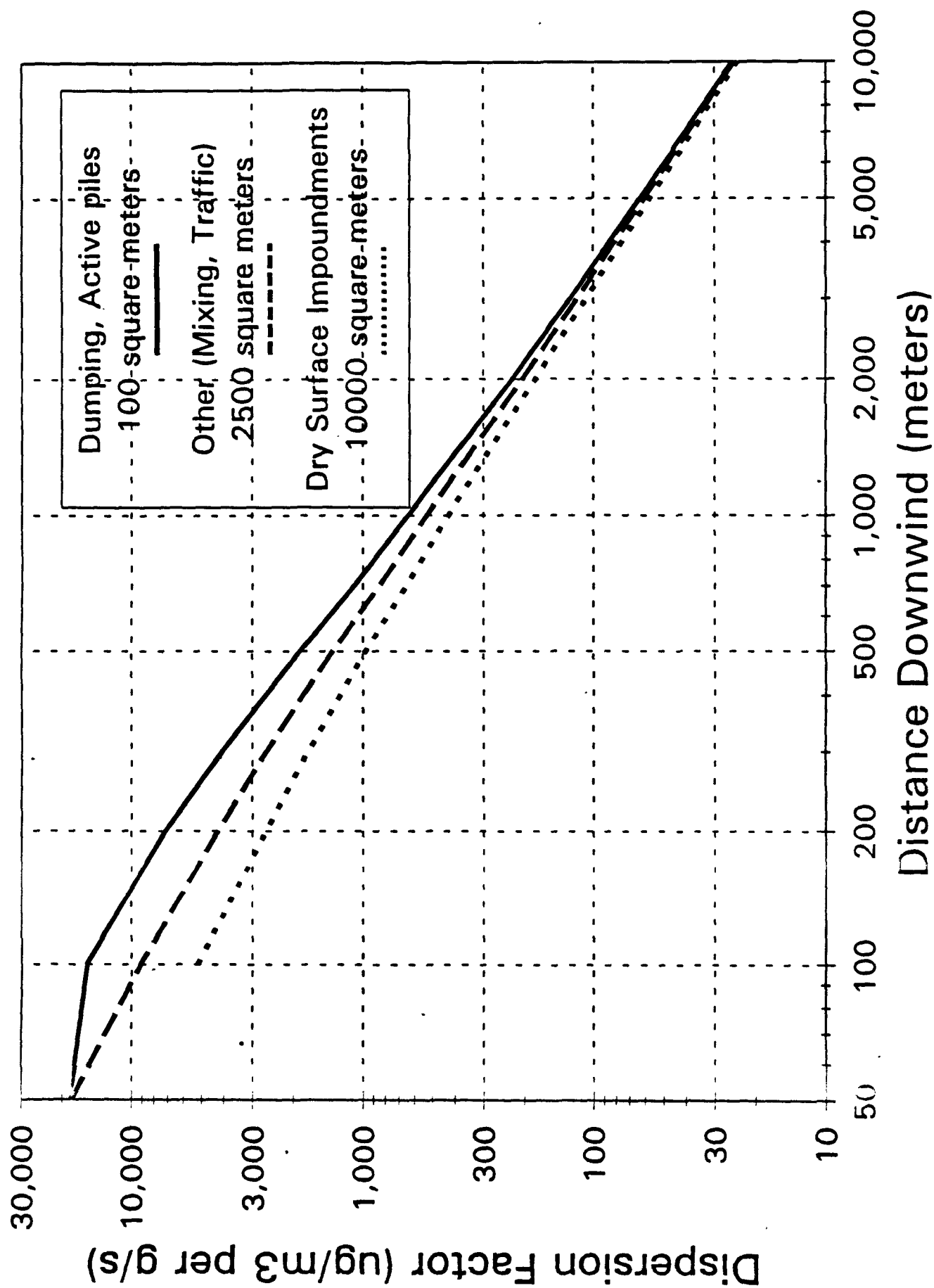


Figure 2. One-Hour Average Downwind Dispersion Factor Versus Distance for Materials Handling Processes With No Air Controls

$$C_m = (ER)(F) \quad (\text{Eq. 11})$$

$$C_a = (ER)(F)(0.08) \quad (\text{Eq. 12})$$

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 12 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 0.08.¹⁵ Factors up to 0.20 have been suggested for certain specific locations.¹⁶ Graphical estimation tools in lieu of these factors also have been proposed.^{7,17} 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.¹⁸ 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.

Table 5.

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

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 ⁻⁴ 70-year Risk (μg/m ³)	RfC-Based Concentrations for Non-Carcinogenic Effects (μg/m ³)	Concentrations Based on Occupational Exposure ^d	
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	-- ^{ee}	(4e-01) ^b	--	400	1,780	17,800	
5	Acetonitrile	75-05-8	-- ^e	5e-02 ^f	--	50	67	670	
6	Acrolein	107-02-8	-- ^{ee}	2e-05 ^e	--	0.02	0.23	2.30	
7	Acrylic acid	79-10-7	-- ^e	3e-04 ^e	--	0.3	5.90	59	
8	Acrylonitrile	107-13-1	6.8e-05 ^e	2e-03 ^e	0.015 ^e	2	4.30	43	
9	Allyl alcohol	107-18-6	-- ^e	(2e-02) ^b	--	20	4.80	48	
10	Allyl chloride	107-05-1	-- ^{ee}	1e-03 ^e	--	1	3.00	30	
11	Aniline	62-53-3	1.6e-6 ^b	1e-03 ^e	0.63	1	7.60	76	
12	Anthracene	120-12-7	-- ^{ee}	(1e+00) ^b	--	1,000	0.20	2.00	
13	Benzaldehyde	100-52-7	-- ^e	(4e-01) ^b	--	400	--	--	
14	Benzene	71-43-2	8.3e-06 ^e	-- ^e	0.12	--	32	320	
15	Benzoic acid	65-85-0	-- ^{ee}	(1.4e+01) ^b	--	14,000	--	--	
16	Benzyl alcohol	100-51-6	-- ^e	(1e+00) ^b	--	1,000	--	--	
17	Benzyl chloride	100-44-7	5e-05 ^b	-- ^e	0.02	--	5	50	
18	Bromoform	75-25-2	1.1e-06 ^e	(7e-02) ^b	0.91	70	5	50	
19	1,3-Butadiene	106-99-0	2.8e-04 ^e	-- ^e	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	-- ^{ee}	(4e-01) ^b	--	400	152	1,520	

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 ⁻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		
							Lowest OEL/1000 ($\mu\text{g}/\text{m}^3$)		
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	-- ^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	-- ^g	(2e-01) ^b	--	200	22	220	
37	o-Cresol	95-48-7	-- ^g	(2e-01) ^b	--	200	22	220	
38	p-Cresol	106-44-5	-- ^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 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)		
46	Dibutyl-O-Phthalate	84-74-2	— ^{ee}	(4e-01) ^b	—	400	5.00	50	
47	o-Dichlorobenzene	95-50-1	— ^{ee}	2e-01 ^f	—	200	150	1,500	
48	p-Dichlorobenzene	106-46-7	6.6e-6 ^b	8e-01 ^f	0.15	800	450	4,500	
49	Dichloroethylether	111-44-4	3.3e-04 ^e	—	3.0e-03	—	29	290	
50	Dichlorodifluoromethane	75-71-8	— ^e	(0.7) ^b	—	200	4,950	49,500	
51	1,1-Dichloroethane	75-34-3	— ^{ee}	5e-01 ^f	—	500	400	4,000	
52	1,2-Dichloroethane	107-06-2	2.6e-05 ^e	—	0.038 ^c	—	4.00	40	
53	1,1-Dichloroethylene	75-35-4	5e-05 ^e	(3e-02) ^b	0.020	30	4.00	40	
54	cis-1,2-dichloroethylene	156-59-2	— ^{ee}	(4e-02) ^b	—	40	790	7,900	
55	trans-1,2-dichloroethylene	156-60-5	— ^e	(7e-02) ^b	—	70	790	7,900	
56	Dichloromethane	75-09-2	4.7e-07 ^e	3e+00 ^f	2.1	3,000	174	1,740	
57	Dichloromonofluoromethane	75-43-4	—	—	—	—	40	400	
58	1,2-Dichloropropane	78-87-5	2e-05 ^b	4e-3 ^c	0.050	4	347	3,470	
59	1,3-Dichloropropene	542-75-6	3.7e-05 ^f	2e-02 ^c	0.027	20	4.5	45	
60	1,2-Dichloro-1,1,2,2-Tetrafluoroethane	76-14-2	—	—	—	—	6,990	69,900	
61	Diethanolamine	111-42-2	—	—	—	—	13	130	
62	Diethyl amine	109-89-7	—	—	—	—	30	300	
63	N,N-Dimethylaniline	121-69-7	— ^e	(7e-03) ^b	—	7	25	250	
64	Diethyl ether	60-29-7	—	(7e-01) ^b	—	700	1,200	12,000	
65	Dimethylamine	124-40-3	— ^e	— ^c	—	—	9.2	92	
66	Dimethyl formamide	68-12-2	— ^e	3e-02 ^c	—	30	30	300	
67	1,1-Dimethyl hydrazine	57-14-7	1e-03 ^f	— ^c	1e-03	—	1	10	
68	2,4-Dinitrophenol	51-28-5	— ^e	(7e-03) ^b	—	7	—	—	

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)	
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/($\mu\text{g}/\text{m}^3$)	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 ⁻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 Lowest OEL/1000 ($\mu\text{g}/\text{m}^3$)		
92	Hydrazine	302-01-2	4.9e-03 ^c	-- ^c	2.0e-04	--	0.1	1	
93	Hydrochloric acid	7647-01-0	-- ^c	7e-03 ^c	--	7	7.5	75	
94	Hydrogen cyanide	74-90-8	-- ^c	(0.07) ^b	--	70	11	110	
95	Hydrogen Sulfide	7783-06-4	-- ^c	9e-04 ^c	--	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	-- ^c	-- ^c	--	--	983	9,830	
99	Isopropyl amine	75-31-0	--	--	--	--	12	120	
100	Isopropylbenzene	98-82-8	-- ^c	(1.4e-01) ^b	--	140	245	2,450	
101	Methanol	67-56-1	-- ^c	(2e+00) ^b	--	2,000	260	2,600	
102	Methyl acetate	79-20-9	-- ^c	(4e+00) ^b	--	4,000	606	6,060	
103	Methyl acrylate	96-33-3	-- ^c	(1.1e-01) ^b	--	110	35	350	
104	Methyl amine	74-89-5	--	--	--	--	6.4	64	
105	Methyl bromide	74-83-9	-- ^c	5e-3 ^c	--	5	19	190	
106	Methyl-tert-butyl-ether	1634-04-4	-- ^c	5e-01 ^c	--	500	--	--	
107	Methyl chloride	74-87-3	1.8e-06 ^c	-- ^c	0.55	--	103	1,030	
108	Methylcyclohexane	108-87-2	--	3e+00 ^c	--	3,000	1,600	16,000	
109	Methyl-ethyl-ketone	78-93-3	-- ^c	1e-00 ^c	--	1,000	590	5,900	
110	Methyl formate	107-31-3	--	--	--	--	246	2,460	
111	Methyl hydrazine	60-34-4	3e-04 ^b	-- ^c	3.3e-03	--	0.38	3.8	
112	Methyl iodide	74-88-4	-- ^c	-- ^c	--	--	10	100	
113	Methyl-Isobutyl-Ketone	108-10-1	-- ^c	8e-02 ^f	--	80	205	2,050	
114	Methyl isocyanate	624-83-9	-- ^c	-- ^c	--	--	0.047	0.47	

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	
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	-- ^e	--	--	--	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 ^c	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	-- ^e	-- ^e	--	--	0.20	2	
130	Phenol	108-95-2	-- ^e	(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 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)		
138	Propionaldehyde	123-38-7	—	—	—	—	—	—	—
139	Propionic acid	79-09-4	— ^c	— ^c	—	—	30	30	300
140	n-Propyl-Acetate	109-60-4	—	—	—	—	835	835	8,350
141	Propylene oxide	75-56-9	3.7e-06 ^c	3e-02 ^c	0.27	30	48	48	480
142	1,2-Propylenimine	75-55-8	— ^c	— ^c	—	—	4.7	4.7	47
143	Pyridine	110-86-1	— ^c	(4e-03) ^b	—	4	15	15	150
144	Quinone	106-51-4	— ^c	— ^c	—	—	0.4	0.4	4
145	Styrene	100-42-5	— ^c	1.0e+00 ^c	—	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 ^{a,c}	— ^c	0.017	—	6.90	6.90	69
148	Tetrachloroethylene	127-18-4	5.8e-07 ^c	(3.5e-2) ^b	1.7	35	170	170	1,700
149	Tetrahydrofuran	109-99-9	— ^c	— ^c	—	—	590	590	5,900
150	Toluene	108-88-3	— ^{a,c}	4e-01 ^c	—	400	375	375	3,750
151	p-Toluidine	106-49-0	5.4e-05 ^b	— ^c	0.019	—	8.80	8.80	88
152	1,1,1-Trichloroethane	71-55-6	— ^{a,c}	1.0e+00 ^d	—	1,000	1,900	1,900	19,000
153	1,1,2-Trichloroethane	79-00-5	1.6e-05 ^{a,c}	1.4e-02 ^c	0.063	14	45	45	450
154	Trichloroethylene	79-01-6	— ^c	— ^c	—	—	269	269	2,690
155	Trichlorofluoromethane	75-69-4	— ^c	7.0e-01 ^f	—	700	5,620	5,620	56,200
156	1,2,3-Trichloropropane	96-18-4	— ^c	2.0e-02 ^c	—	20	60	60	600
157	1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	— ^c	(2.7e+01) ^b	—	27,000	7,600	7,600	76,000
158	Triethylamine	121-44-8	— ^c	7e-3 ^c	—	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/(μg/m ³)	Risk-Specific Concentrations for Carcinogenicity	RfC-Based Concentrations for Non-Carcinogenic Effects (μg/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	-- ^c	2e-01 ^c	--	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	-- ^c	(7) ^b	--	7000	434	--	4,340
167	o-Xylene	95-47-6	-- ^c	(7) ^b	--	7000	434	--	4,340
168	p-Xylene	106-42-3	-- ^c	-- ^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)	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 ^d 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 ^e	(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 ^a	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 ^e	(2.1e-04) ^b	2.7e-03	0.21	0.5	5	
12	Chrysene	218-01-9	--	--	--	--	0.2 ^a	2.0 ^a	
13	Cresol	1319-77-3	-- ^{a,e}	(2e-01) ^b	--	200	22	220	
14	Dioxin (2,3,7,8-TCDD)	1746-01-6	--	--	--	--	--	--	
15	Dibenzofuran	132-64-9	-- ^{a,e}	-- ^e	--	--	--	--	
16	Dibenzo(a,h)anthracene	53-70-3	-- ^e	-- ^e	--	--	--	--	
17	Di-n-butylphthalate	84-74-2	-- ^{a,e}	(3.5e-01) ^b	--	350	5	50	
18	Ethylenamine	593-67-9	--	--	--	--	--	--	
19	Fluoranthene	206-44-0	-- ^{a,e}	(1.4e-01) ^b	--	140	--	--	
20	Fluorene	86-73-7	-- ^{a,e}	(1.4e-01) ^b	--	140	--	--	
21	Heptachlor	76-44-8	1.3e-03 ^e	-(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/m³)	Chronic Toxicity ^a Inhalation RfC (mg/m³)	Long-Term Action Levels				Short-Term Action Levels ^d Lowest OEL/100 (μg/m³)
					Risk-Specific Concentrations for Carcinogenicity 10 ⁻⁴ 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)		
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	-- ^g	(3.5e-01) ^b	--	350	1	10	
26	2-Methylnaphthalene	91-57-6	--	--	--	--	--	--	
27	p-Nitrosodiphenylamine	156-10-5	--	--	--	--	--	--	
28	Nitrobenzene	98-95-3	-- ^g	2e-3	--	2.0	5	50	
29	PCBs	1336-36-3	2.2e-03 ^b	-- ^g	4.5e-04	--	--	--	
30	PAHs	--	--	--	--	--	0.2 ^h	2.0 ^h	
31	Parathion	56-38-2	-- ^g	(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).

^g 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/m³)	Chronic Toxicity ^a Inhalation RfC (mg/m³)	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 ^d		
							Lowest OEL/1000 (μg/m³)		
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 ^{c,e}	4e-04 ^c	ND	0.40	0.50	5.00	
10	Mercury (vapor)	7439-97-6	ND ^{c,e}	3e-04 ^f	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.

Equation 13 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 13 assumes continuous exposure (24 hours/day, 365 days/year for 70 years) to the estimated annual average concentration in air.

$$R = (C_a)(IUR) \quad (\text{Eq. 13})$$

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 12, ($\mu\text{g}/\text{m}^3$); 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 13. 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 $\text{mg}/\text{kg}/\text{day}$) were multiplied by 70 kg (average body weight of an adult), then divided by 20 m^3/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 as the best available approach 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)¹⁹ and the American Conference of Governmental Industrial Hygienists (ACGIH).²⁰ 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 12.

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 11 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 area sources of PM emissions 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 that a Superfund site exists in Durham, NC and soil is excavated from a pit and transported to a storage pile 500 m away. The backhoe moves 4 m³ of soil at a time, and dumps the excavated soil directly into trucks. Ten truckloads a day are moved with each truck containing 20 m³ of soil. In addition, a bulldozer works over the storage pile for an hour each day. The soil moisture content is 10% and the average wind speed at the site is 2 m/sec. The lead content of the soil is 100 µg/g. The removal is expected to be in continual operation for 20 days (1.728×10^6 seconds). The nearest off-site downwind receptor is 400 meters away. The site also contains a one acre dry surface impoundment. The soil has a silt content of 8%. A subset of the contaminated soil is excavated every other day, placed in an (active) storage pile, and then fed into a stabilization process. The storage pile has a surface area of 2000 m². One thousand kilograms per day of the stabilized material is placed in a lined portion of the dry surface impoundment.

Step 2 Estimate the PM₁₀ emission rate from each activity. To find the total PM₁₀ emissions from this site, first convert the 20 m³ of soil for ten trucks to a mass, using the default soil density of 1.5 g/cm³:

$$(20 \text{ m}^3)(1.5 \text{ g/cm}^3)(0.001 \text{ kg/g})(10^6 \text{ cm}^3/\text{m}^3)(10 \text{ trucks}) = 300,000 \text{ kg soil.}$$

The particle size multiplier for < 10 μm is 0.35. Use Equation 1 for the backhoe emissions:

$$ER = 0.35 * (0.0016) * 300,000 * (2/2.2)^{1.3} / (10/2)^{1.4} = 15.6 \text{ g.}$$

This number should be multiplied by 2, because the soil will be dumped once into the trucks and dumped a second time onto the storage pile. Thus the total emissions from dumping are 31 g and the average emission rate is 31 g/day (3.6 x 10⁻⁴ g/sec).

To find the lead emissions from the backhoe operations, first calculate the fraction of lead in the windblown dust using Equation 7 with the lead content of the soil (100 μg/g) and the enrichment factor for lead from Table 2 (7.34):

$$X_i = (100)(7.34)(10^{-6}) = 7.34 \times 10^{-4} \text{ (g lead/g windblown dust)}$$

This value is then used with the average emission rate calculated above (31 g/day) and Equation 6:

$$EF_{\text{lead}} = (7.34 \times 10^{-4})(31) = 0.023 \text{ g/day (2.6 x 10}^{-7} \text{ g/sec).}$$

To find the PM₁₀ emissions from transport, the silt content of the unpaved surface is needed, as well as the number of wheels per truck, the vehicle weight, and the vehicle speed. Assume that these all equal the default values from Table 1. The number of days with precipitation > 0.01" for North Carolina is found from Figure 1. From Equation 5, the transport emissions are:

$$EF = 610 (8/12)(20/48)(30/2.7)^{0.7}(10/4)^{0.5}(365-120)/365 = 970 \text{ g/km.}$$

A total of 10 truckloads are driven over a 1 km roundtrip, so the total emissions (ignoring the weight difference between the empty and full truck) are 9,700 g or 9.7 kg. The average emission rate is 9.7 kg/day.

Finally, to find the emission rate due to the bulldozing, use Equation 3:

$$ER = \frac{0.094 (8)^{1.5}}{(10)^{1.4}} = 0.085 \text{ g/sec}$$

Since the activity is underway for one hour, the total emissions are about 300 g per day.

Example calculations for particulate matter emissions of less than 10 microns from the other sources are given below. Emissions from the surface impoundment are estimated using Equation 8. The surface area of the impoundment is one acre or 4050 m². The particle size multiplier for < 10 μm is 0.5, the time between disturbances is two days, and the default erosion potential is 33 g/m². The emission rate from the surface impoundment is:

$$ER = \frac{(0.5)(4050)(33)}{(2)(86,400)} = 0.39 \text{ g/sec (33,000 g/day)}$$

Particulate matter from wind erosion of continuously active piles can be estimated using Equation 9. The number of rainy days from Figure 1 is 120:

$$1.9 \left(\frac{8}{15} \right) \left(\frac{365 - 120}{235} \right) \left(\frac{20}{15} \right) = 1.41 \text{ g/m}^2\text{-day}$$

Assuming 50% of the TSP is PM₁₀, the emissions of PM₁₀ from the storage pile are:

$$ER = (1.41)(50/100)(2000) = 1400 \text{ g/day.}$$

The emissions of PM₁₀ emissions from the transfer of the stabilized waste can be estimated using Equation 10 (assuming that all the PM is PM₁₀):

$$E = \frac{0.00056 \left(\frac{2}{2.2} \right)^{1.3} (1,000)}{\left(\frac{2}{2} \right)^{1.4}} = 0.49 \text{ g per day}$$

The emissions can be summed from all activities. Emissions of particulate matter are equal to the sum of emissions from the backhoe operation, transport, bulldozer operation, dry surface impoundment, storage piles, and waste transfer:

$$31 + 9,700 + 300 + 33,000 + 1400 + 0.49 = 44,000 \text{ g/day} = 0.51 \text{ g/sec}$$

Emissions from the dry surface impoundment and transfer operations represent the vast majority of the PM_{10} emissions. Assuming all of the soil is contaminated with lead, then the emission rate for lead is $(7.34 \times 10^{-4})(0.51) = 3.7 \times 10^{-4}$ g/sec. The fraction of lead in the windblown dust, 7.34×10^{-4} , was calculated in Step 2.

Step 3

Estimate the downwind ambient air concentrations. Several activities are performed at this site, so separate calculations could be performed for the backhoe emissions, transport emissions, surface impoundment emissions, and so forth. For simplicity, all emission sources are assumed to be located together and only the most conservative dispersion factor is used. From Figure 2, the maximum dispersion factor at a distance of 400 meters for any of the activities is approximately 3000 ug/m^3 per g/sec emission rate. This corresponds to an annual average dispersion factor of 240 ug/m^3 per g/s ($3000 \times 0.08 = 240$). The ambient air concentrations estimated from Equations 11 and 12 are presented in Table 8. Using Equation 11, the hourly average ambient air concentration for lead would be:

$$C_m = (0.00037)(3000) = 1.1 \text{ ug}/m^3$$

Using Equation 12, the annual average air ambient concentration for lead would be:

$$C_a = (0.00037)(240) = 0.089 \text{ ug}/m^3$$

Step 4

Compare the downwind concentrations to the action level ambient air concentrations. The short-term and long-term action levels from Table 7 for lead are presented in Table 9. The estimated maximum hourly ambient concentration for lead is slightly below the applicable action level. The annual average ambient concentration also is somewhat below the long-term action level.

Step 5

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 warranted. 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.

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
Lead	100	3.7×10^{-4}	1.1	0.089

Table 9.

Action Level Concentrations

	Table 7 Action Levels $\mu\text{g/m}^3$	
	Short-Term	Long-Term
Lead	1.50	0.15

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.

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