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*The findings and opinions expressed in this paper are the personal views of the authors, and do not necessarily reflect the position, recommendation, or policy of the Massachusetts Department of Environmental Protection.*

## **REAL-TIME AIR MONITORING AT CONSTRUCTION AND REMEDIATION SITES TO ESTIMATE RISKS OF CONTAMINATED DUST MIGRATION**

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### **ABSTRACT**

*The excavation and disturbance of contaminated soils during construction and cleanup projects can result in the liberation and offsite migration of contaminated dust. The establishment of action levels for dust exposure which are measurable by real-time air monitoring equipment at such sites is critical to limit exposures to the public. By assuming that dust contaminant loadings are proportional to the concentration of contaminants detected in site soil, dust screening criteria were generated which may be measured by a real-time quantifiable means. Allowable exposure levels for common contaminants in soil-derived dust were calculated using a risk based approach. Simple graphs of action levels are provided. Given a known contaminant concentration in soil, an appropriate dust action level may be selected. Calculated action levels were also compared to EPA National Ambient Air Quality Standards for particulate matter.*

### **BACKGROUND**

Construction and remediation projects in contaminated areas can result in the generation of soil-derived dust. Contaminants in dust may be transported to nearby receptors where exposures can occur. Potential offsite exposures can be one of the primary concerns of neighbors or public groups if the construction or remediation project is taking place within or adjacent to a residential area.

Real-time air monitoring may be continuously employed at the fenceline of such sites to ensure that dust levels migrating offsite are protective of public health. Real-time monitoring is more favorable than traditional air sampling techniques because the results are known immediately. If an action level is approached or exceeded at the fenceline, action can be taken promptly to address/mitigate the problem, e.g., dust control or work stoppage. Using standard air sampling approaches, an exceedence of a risk limit is not known until days or weeks after the fact. The use of real-time air monitoring can assure neighboring communities and regulatory agencies that dust migration and potential off-site exposures will be controlled during the project.

Since portable real-time air monitoring equipment is widely available and commonly used to measure particulate concentrations in ambient air, fence-line dust action levels for common soil contaminants were developed. Standard risk assessment methodologies and risk management standards were employed to calculate acceptable dust exposures. The term “action level” implies that if it is exceeded or approached, action should be taken to reduce the dust level to prevent any significant offsite exposures. Simple graphs of action levels are provided. Given a known contaminant concentration in soil, an appropriate action level may be selected. Calculated action levels were also compared to USEPA’s National Ambient Air Quality Standards (NAAQS) for particulate matter.

## **PARTICLE SIZE DISTRIBUTIONS**

The particle size distribution of dust is an important factor in determining potential exposures. Action levels are presented as “PM-10” values. PM-10 refers to dust or soil particles having a diameter of 10 microns or less. PM-30 refers to dust or soil particles having a diameter of 30 microns or less. Particles with diameters of 10 microns or less are considered to be the respirable fraction. Particles with diameters up to 30 microns can be deposited in the upper respiratory system and ingested. This is controlled by the body’s natural defense mechanisms as described below.

Larger (PM-30) particles are trapped in the nasal and pharyngeal passages. Smaller (PM-10) particles which don’t reach the lung can be deposited in the trachea and bronchial tubes. It has been suggested that only particles with an aerodynamic diameter of 1 micron or less are able to penetrate to the lung. Mucous secretions which line the respiratory system trap the particles and tiny cilia act to move them to the back of the throat where they can be swallowed, i.e., ingested. This defense mechanism is called the mucociliary escalator. The body has the ability to cleanse the respiratory system of larger dust particles, however, once very small particles have entered the alveolar sacs of the lung, the mucociliary escalator cannot remove them. (Emilcott Associates, Inc., 1991)

Particles larger than PM-30 are not considered biologically relevant via the inhalation exposure route, however, may be important if significant deposition of larger particles occurs around the site, resulting in incidental (e.g., hand-to-mouth) ingestion. (MADEP/Office of Research and Standards, 1997)

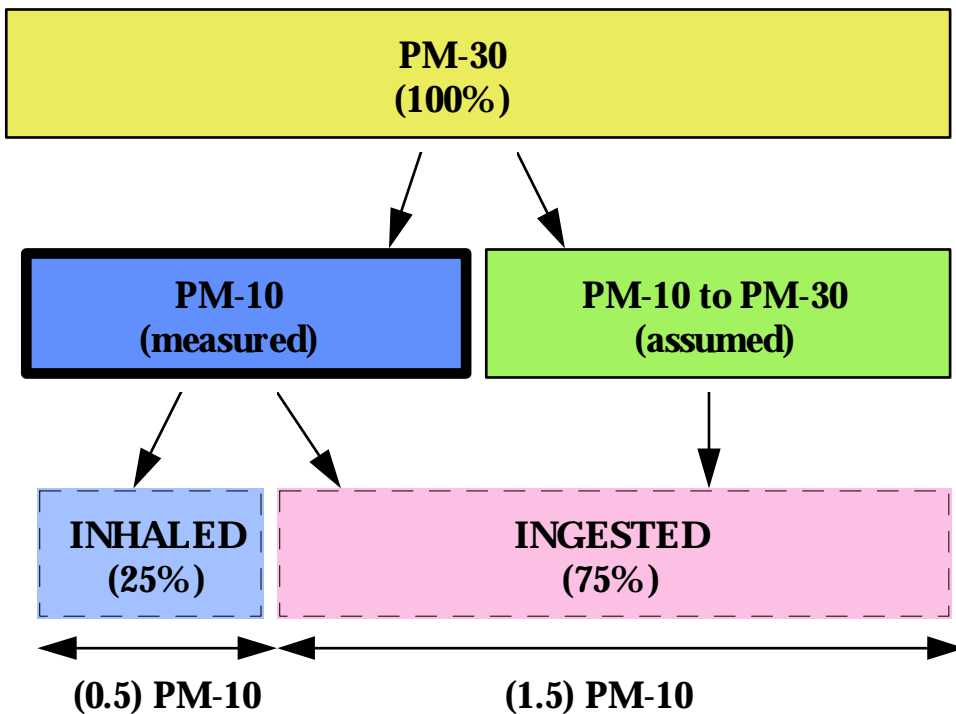
## **RISK ASSESSMENT METHODOLOGY**

Standard risk assessment procedures and guidelines were used to derive PM-10 action levels for common soil contaminants. Both carcinogenic and noncarcinogenic effects were evaluated. The action level was based on the lower of the cancer or noncancer level. A target Hazard Index (HI) of 0.2 was used for noncancer effects. A target Excess

Lifetime Cancer Risk (ELCR) of one in a million (1/1,000,000) was used for the carcinogenic evaluations. The calculations are provided in Appendix A.

As illustrated in Figure 1, for the purpose of calculating dust action levels, an assumption was made that 50% of the PM-10 fraction reaches the lung and is inhaled and 50% is ingested. Another assumption was made that the PM-10 fraction is equivalent to the particulate fraction larger than PM-10 yet smaller than PM-30. (Manganaro and Zewdie, 1994) The source and basis of these assumptions are presented in more detail in several documents prepared by MADEP's Office of Research and Standards and are listed in Appendix C.

**Figure 1. Assumed Size/Fate of Particles.**



Since real-time air monitoring equipment is designed to measure PM-10 dust and both ingestion and inhalation exposures can be estimated by knowing the PM-10 concentration, action levels for PM-10 were developed.

It was assumed that the construction/remediation project takes place in a residential neighborhood. The project lasts for one year. Dust is generated at the site 24 hours a day, 7 days a week, for an entire year. Routes of exposure include inhalation of soil-derived dust and ingestion of inhaled soil-derived dust. The receptor is a 1-2 year old child. This exposure scenario may seem too conservative for several reasons. In certain areas, e.g., New England, snow and freezing conditions can minimize dust generation and outdoor exposures for several months of the year. However, in other parts of the US, these exposure parameters may be more realistic. If contaminated soil is covered during

non-work hours, the exposure duration and frequency could be reduced to the hours when active soil disturbance is ongoing, (e.g., 8 hours a day, 5 days a week). For the purpose of developing the generic action levels presented in this paper, conservative exposure parameters were selected. The use of these exposure parameters may be re-evaluated based on site-specific factors. The exposure parameters and toxicity values used are provided in Appendix B.

The soil contaminants which were evaluated are listed as follows:

- Metals:

Arsenic\*, Barium, Cadmium\*, Chromium (III and VI\*), Lead, Mercury, Selenium, and Silver.

- Polycyclic Aromatic Hydrocarbons (PAHs):

Benzo(a)pyrene\* and Naphthalene.

- Petroleum Hydrocarbons:

Non-volatile fractions of Total Petroleum Hydrocarbons (TPH).

The asterisk denotes the contaminants for which carcinogenic effects were evaluated. Non-carcinogenic effects were evaluated for all contaminants except Benzo(a)pyrene.

For the PAHs, one compound was selected for evaluation of carcinogenic effects and one for evaluation of noncarcinogenic effects. Based upon a review of the relative toxicities and carcinogenicities of the many compounds which comprise PAHs, Benzo(a)pyrene and Naphthalene were selected as the “worst case” compounds for the evaluation of carcinogenic effects and non-carcinogenic effects, respectively.

For non-volatile fractions of TPH, conservative surrogate toxicity values for Naphthalene were used. If volatiles are present at a site, further evaluation of vapor phase exposures during remediation would be warranted for nearby receptors. Also, for the purpose of evaluating contaminated dust exposures, Naphthalene would not be an appropriate surrogate for TPH if volatile hydrocarbons, like Xylenes, were present.

## **USEPA NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)**

USEPA has developed National Ambient Air Quality Standards (NAAQS) for PM-10, which are listed in Table 1. These standards are based on adverse health impacts due to the inhalation of particulates in this size range. These standards are not contaminant specific and apply to all dusts, regardless of the source or type. The particulate limits are based on the hazards associated with these particles due to their size alone.

Recently, USEPA has established NAAQS for particles in the PM-2.5 range. USEPA has found that there are significant adverse health impacts due to the inhalation of fine particles which penetrate deeply into the lung. These new standards are also listed in Table 1. Primary sources of PM-2.5 include combustion sources and vehicle exhaust.

Table 1. USEPA National Ambient Air Quality Standards (NAAQS).

Particulate Size	24-Hour Standard ug/m <sup>3</sup>	Annual Standard ug/m <sup>3</sup>
PM-10	150	50
PM-2.5	65	15

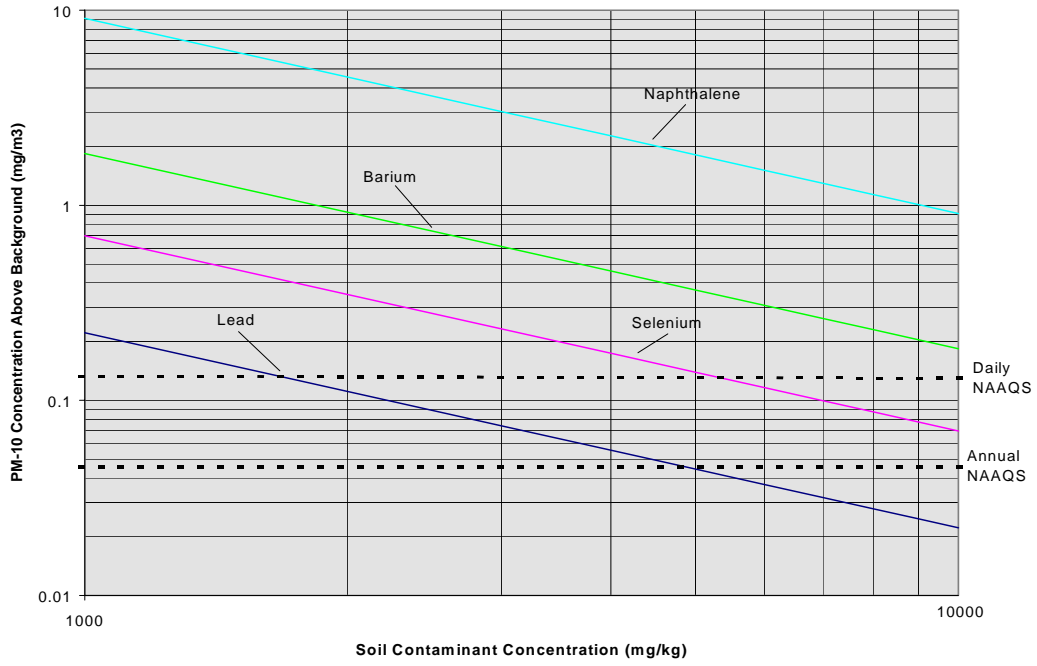
For the construction and remediation scenario described here, the derivation of PM-2.5 action levels was not considered appropriate for two reasons. Firstly, the ingestion pathway for contaminated dust may be an important route of exposure and should not be left out. By using the approach described, exposures to the lung and gastrointestinal (GI) tract could be evaluated by knowing the PM-10 concentration. Also, the sources of PM-2.5 would not typically be construction and remediation sites, as excavation and soil moving activities tend to stir up larger sized dust particles.

**DISCUSSION OF DERIVED ACTION LEVELS/CONCLUSIONS**

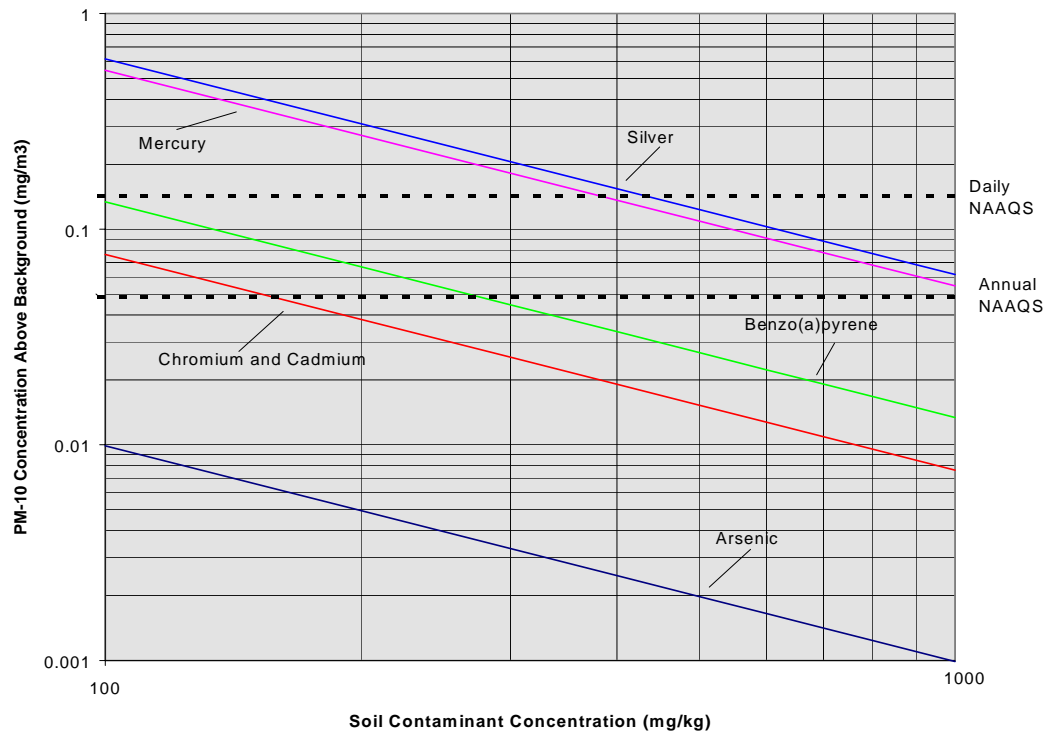
The action levels are presented in Figures 2 and 3. Due to the wide variability of toxicity values used for the contaminants of interest, a wide range of action levels were generated. For illustrative purposes, a “high range” and “low range” graph were developed. “High range” and “low range” refer to the range of soil contaminant concentrations. Figure 2, as the “high range” graph, depicts the soil contaminant concentrations along the X-axis for Naphthalene, Barium, Selenium and Lead from 1,000 to 10,000 mg/kg. Figure 3, as the “low range” graph, depicts the soil contaminant concentrations along the X-axis for Silver, Mercury, Benzo(a)pyrene, Cadmium, Chromium (III and VI), and Arsenic from 100 to 1,000 mg/kg. As the soil contaminant concentrations increase, the acceptable dust exposure (action) levels decrease.

The action level is presumed to be applicable to the dust concentration as measured above background. It is presumed that upwind and downwind monitoring will be performed, so that the upwind dust concentration can be subtracted from the downwind dust concentration in order to measure the impacts from the monitored site. Background (upwind) dust concentrations cannot be controlled at the site of interest, nor should background exposures be included in the assessment of impact from the site of concern.

**Figure 2. PM-10 Fenceline Action Levels.**



**Figure 3. PM-10 Fenceline Action Levels.**



The USEPA NAAQS for PM-10 are also shown as dashed lines in Figures 2 and 3. These values are shown for relative comparison purposes only. In contrast to the derived action levels, the NAAQS would apply to background levels of dust and, therefore, the actual NAAQS compliance levels would be somewhat lower than as shown on these graphs. It is useful to depict the NAAQS here, because compliance with NAAQS may obviate the need for developing a site-specific action level which may be higher than the NAAQS.

Upon review of the action levels presented in Figures 2 and 3, the following conclusions are offered:

- If the daily NAAQS is used as the fenceline action limit, a more stringent action level would be needed for sites where the Lead concentration in soil exceeds approximately 1,750 mg/kg or where the Selenium concentration in soil exceeds approximately 5,000 mg/kg.
- For soil concentrations up to 10,000 mg/kg of Naphthalene or Barium, employing the daily NAAQS at the fenceline as an action level would be protective of offsite impacts of contaminated dust migration.
- For soil concentrations less than approximately 400 mg/kg of Silver or Mercury, employing the daily NAAQS as an action level would be protective.
- For some of the more toxic contaminants, e.g., Benzo(a)pyrene, Cadmium, Chromium and Arsenic, site-specific action levels may need to be employed.
- For soil concentrations of Arsenic greater than 100 mg/kg, the ability of a real-time dust monitoring instrument to accurately quantify dust concentrations at the calculated action levels should be considered.

The action level for Benzo(a)pyrene is the only one which is based on carcinogenic effects; all of the others presented in Figures 2 and 3 are based on noncarcinogenic effects.

## **LIMITATIONS AND UNCERTAINTIES**

As with any risk assessment, there are limitations and uncertainties associated with this methodology. The recommended action levels would not be appropriate for construction/remediation projects longer than one year in duration. Similarly, the assumptions regarding the fate of inhaled particles represent uncertainties in the validity of the calculated action levels. These uncertainties include exposure assumptions about the size ranges of particles evaluated, assumed relative percentages of PM-10 which are inhaled and ingested, and assumed ratios of PM-10 to PM-30.

The assumption that the soil contaminant concentration at a site is equivalent to the dust contaminant concentration is another source of uncertainty. Smaller particles tend to adsorb more contaminants than larger particles due to their greater proportional surface area. Smaller particles also tend to become airborne more quickly and travel further distances. Site-specific information regarding the type of contaminant, soil type and moisture content may be evaluated to determine if this assumption should be modified. This factor should also be evaluated by site-specific data collection during the initial stages of the construction project. Since the exposure scenario presumes a full year's exposure, air sampling should be performed during the initial weeks of the project. If the sampling results indicate that dust contaminant concentrations exceed soil contaminant concentrations, there is time to adjust the action levels to ensure that the risk limits are not exceeded for a full year's exposure.

Finally, the maintenance and calibration of field monitoring equipment is vital in ensuring that measured dust levels are accurate.

## **CONCLUSIONS**

Dust mitigation measures are prudent at all construction and remediation sites. Visible dust should be controlled at all times. Upwind and downwind monitoring stations should be determined on a daily basis. Limited air monitoring by conventional particulate sampling procedures are recommended to confirm dust concentrations migrating off-site and contaminant levels.

The action levels presented here are intended as generic dust action levels for a non-specific site. The procedures and assumptions presented here for calculating dust action levels at construction and remediation sites may need to be modified depending on site-specific factors.

## **DISCLAIMER**

The findings and opinions expressed in this paper are the personal views of the authors, and do not necessarily reflect the position, recommendation, or policy of the Massachusetts Department of Environmental Protection.

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**APPENDIX A -  
DERIVATION OF ACTION LEVELS**

**I. Derivation of Action Levels Based on Exposures to Non-carcinogens (As, Ba, Cd, Cr+3 and +6, Pb, Hg, Se, Ag and Naphthalene):**

**Exposure Pathway 1 - Absorption through GI tract:**

$$ADD_{\text{soil-inh/GI}} = \frac{[\text{OHM}] * \text{VR} * 1.5 \text{ PM-10} * \text{RAF} * \text{EF} * \text{ED} * \text{EP} * \text{C1}_{\text{NC}} * \text{C2}_{\text{NC}}}{\text{BW} * \text{AP} * \text{C3}_{\text{NC}}}$$

$$\text{if: } \text{EXP1}_{\text{NC}} = \frac{[\text{OHM}] * \text{VR} * 1.5 * \text{RAF} * \text{EF} * \text{ED} * \text{EP} * \text{C1}_{\text{NC}} * \text{C2}_{\text{NC}}}{\text{BW} * \text{AP} * \text{C3}_{\text{NC}}}$$

$$\text{then: } ADD_{\text{soil-inh/GI}} = \text{PM-10} * \text{EXP1}_{\text{NC}}$$

where:

ADD<sub>soil-inh/GI</sub> = Average Daily Dose of inhaled soil which is ingested (mg/kg/day)

[OHM] = Soil concentration of contaminant (mg/kg)

VR = Ventilation Rate (L/min)

PM-10 = Respirable particulate concentration in air (mg/m<sup>3</sup>)

RAF = Relative Absorption Factor (dimensionless)

EF = Exposure Frequency (event/day)

ED = Exposure Duration (hrs/event)

EP = Exposure Period (yrs)

C1<sub>NC</sub> = Conversion factor (m<sup>3</sup>/L)

C2<sub>NC</sub> = Conversion factor (min/hrs)

BW = Body Weight (kg)

AP = Averaging Period (yrs)

C3<sub>NC</sub> = Conversion factor (mg/kg)

**Exposure Pathway 2 - Absorption through lungs:**

$$\text{EPC}_{\text{air}} = \frac{[\text{OHM}] * 0.5 \text{ PM-10} * \text{EF} * \text{ED} * \text{EP} * \text{C4}_{\text{NC}} * \text{C5}_{\text{NC}}}{\text{AP}}$$

$$\text{if: } \text{EXP2}_{\text{NC}} = \frac{[\text{OHM}] * 0.5 * \text{EF} * \text{ED} * \text{EP} * \text{C4}_{\text{NC}} * \text{C5}_{\text{NC}}}{\text{AP}}$$

$$\text{then: } \text{EPC}_{\text{air}} = \text{PM-10} * \text{EXP2}_{\text{NC}}$$

where:

EPC<sub>air</sub> = Exposure Point Concentration in air (mg/m<sup>3</sup>)

C4<sub>NC</sub> = Conversion factor (days/hrs)

C5<sub>NC</sub> = Conversion factor (kg/mg)

**Summation of Exposures:**

$$HI = \frac{ADD_{\text{soil-inh/GI}}}{RfD_{\text{oral}}} + \frac{EPC_{\text{air}}}{RfC}$$

$$HI = \frac{PM-10 * EXP1_{NC}}{RfD_{\text{oral}}} + \frac{PM-10 * EXP2_{NC}}{RfC}$$

$$PM-10 = \frac{HI}{\frac{EXP1_{NC}}{RfD_{\text{oral}}} + \frac{EXP2_{NC}}{RfC}}$$

where:

HI = Target Hazard Index (dimensionless)

RfD<sub>oral</sub> = Reference Dose Concentration (mg/kg/day)

RfC = Reference Concentration (mg/m<sup>3</sup>)

## II. Derivation of Action Levels Based on Exposures to Carcinogens (Cd and Cr+6):

### Exposure Pathway - Absorption through lungs:

$$\text{LADE} = \frac{[\text{OHM}] * 0.5 * \text{PM-10} * \text{EF} * \text{ED} * \text{EP} * \text{C1}_c * \text{C2}_c * \text{C3}_c}{\text{AP}}$$

$$\text{if: } \text{EXP2}_c = \frac{[\text{OHM}] * 0.5 * \text{EF} * \text{ED} * \text{EP} * \text{C1}_c * \text{C2}_c * \text{C3}_c}{\text{AP}}$$

$$\text{then: } \text{LADE} = \text{PM-10} * \text{EXP2}_c$$

$$\text{if: } \text{ELCR} = \text{LADE} * \text{UR}$$

$$\text{then: } \text{LADE} = \frac{\text{ELCR}}{\text{UR}}$$

$$\text{so: } \text{PM-10} * \text{EXP2}_c = \frac{\text{ELCR}}{\text{UR}}$$

$$\text{and: } \text{PM-10} = \frac{\text{LADE}}{\text{EXP2}_c}$$

where:

LADE = Lifetime Average Daily Exposure (ug/m3)

C1<sub>c</sub> = Conversion factor (ug/mg)

C2<sub>c</sub> = Conversion factor (days/hrs)

C3<sub>c</sub> = Conversion factor (kg/mg)

ELCR = Excess Lifetime Cancer Risk (dimensionless)

UR = Unit Risk (1/(ug/m3))

### **III. Derivation of Action Levels Based on Exposures to Carcinogens (As and BaP):**

#### **Exposure Pathway 1 - Absorption through GI tract:**

$$\text{LADD} = \frac{[\text{OHM}] * \text{VR} * 1.5 * \text{PM-10} * \text{RAF} * \text{EF} * \text{ED} * \text{EP} * \text{C4}_C * \text{C5}_C}{\text{BW} * \text{AP} * \text{C6}_C}$$

$$\text{if: } \text{EXP1}_C = \frac{[\text{OHM}] * \text{VR} * 1.5 * \text{RAF} * \text{EF} * \text{ED} * \text{EP} * \text{C4}_C * \text{C5}_C}{\text{BW} * \text{AP} * \text{C6}_C}$$

$$\text{then: } \text{LADD} = \text{PM-10} * \text{EXP1}_C$$

$$\text{if: } \text{ELCR} = \text{LADD} * \text{SF}_{\text{oral}}$$

$$\text{then: } \text{LADD} = \frac{\text{ELCR}}{\text{SF}_{\text{oral}}}$$

$$\text{so: } \text{PM-10} * \text{EXP1}_C = \frac{\text{ELCR}}{\text{SF}_{\text{oral}}}$$

$$\text{and: } \text{PM-10} = \frac{\text{LADD}}{\text{EXP1}_C}$$

where:

LADD = Lifetime Average Daily Dose (mg/kg/day)

C4<sub>C</sub> = Conversion factor (m<sup>3</sup>/L)

C5<sub>C</sub> = Conversion factor (min/hrs)

C6<sub>C</sub> = Conversion factor (mg/kg)

SF<sub>oral</sub> = Slope Factor (1/(mg/kg/day))

#### **Exposure Pathway 2 - Absorption through lungs:**

$$\text{LADE} = \frac{[\text{OHM}] * 0.5 * \text{PM-10} * \text{EF} * \text{ED} * \text{EP} * \text{C1}_C * \text{C2}_C * \text{C3}_C}{\text{AP}}$$

$$\text{if: } \text{EXP2}_C = \frac{[\text{OHM}] * 0.5 * \text{EF} * \text{ED} * \text{EP} * \text{C1}_C * \text{C2}_C * \text{C3}_C}{\text{AP}}$$

$$\text{then: } \text{LADE} = \text{PM-10} * \text{EXP2}_C$$

#### **Summation of Pathways:**

**Exposure Pathway 1 - Absorption through GI tract:**

$$\text{ELCR} = \text{LADD} * \text{SF}$$

$$\text{ELCR} = \text{PM-10} * \text{EXP1}_C * \text{SF}$$

**Exposure Pathway 2 - Absorption through lungs:**

$$\text{ELCR} = \text{LADE} * \text{UR}$$

$$\text{ELCR} = \text{PM-10} * \text{EXP2}_C * \text{UR}$$

**Summation of Pathways:**

$$\text{ELCR} = (\text{PM-10} * \text{EXP1}_C * \text{SF}) + (\text{PM-10} * \text{EXP2}_C * \text{UR})$$

$$\text{ELCR} = \text{PM-10} ((\text{EXP1}_C * \text{SF}) + (\text{EXP2}_C * \text{UR}))$$

$$\text{PM-10} = \frac{\text{ELCR}}{((\text{EXP1}_C * \text{SF}) + (\text{EXP2}_C * \text{UR}))}$$



**APPENDIX B -**  
**TOXICITY VALUES AND EXPOSURE PARAMETERS**

**TABLE 1: TOXICITY VALUES**

Contaminant	RfD <sup>1</sup> (mg/kg/day)	RfC <sup>2</sup> (mg/cu m)	RAF <sup>3</sup> (unitless)	SF <sub>oral</sub> <sup>4</sup> 1/(mg/kg/day)	UR <sup>5</sup> 1/(ug/cu m)
Arsenic	3.0E-04	2.5E-06	1	1.5E+00	4.3E-03
Barium	7.0E-02	5.0E-03 <sup>6</sup>	1	NA <sup>7</sup>	NA
Cadmium	5.0E-04 <sup>8</sup>	2.0E-05	1	NA	1.8E-03
Chromium (III)	1	2.0E-05 <sup>9</sup>	1	NA	NA
Chromium (VI)	2.0E-02	2.0E-05 <sup>9</sup>	1	NA	1.2E-02
Lead	7.5E-04 <sup>10</sup>	1.0E-03	0.5	NA	NA
Mercury	3.0E-04 <sup>9</sup>	3.0E-04 <sup>11</sup>	1	NA	NA
Selenium	5.0E-03	3.0E-03	1	NA	NA
Silver	5.0E-03	1.6E-04 <sup>12</sup>	1	NA	NA
Benzo(a)- pyrene	NA	NA	1 <sup>13</sup>	7.3E+00	1.7E-03 <sup>9</sup>
Naphthalene and TPH <sup>14</sup>	4.0E-02 <sup>9</sup>	7.1E-02	1	NA	NA

1 - Reference Dose. Values in this column were obtained from the US EPA's *Health Effects Assessment Summary Tables (HEAST)* unless otherwise noted. Subchronic values were used if available, otherwise chronic values were used.

2 - Reference Concentration. Values in this column are *Allowable Threshold Concentrations* (analogous to an inhalation RfC) listed in MADEP/Office of Research and Standards' guidance documents unless otherwise noted. Subchronic values were used if available, otherwise chronic values were used.

3 - Relative Absorption Factor. Subchronic soil ingestion RAFs were obtained from *Background Documentation for the Development of the MCP Numerical Standards*, MADEP/Bureau of Waste Site Cleanup and Office of Research and Standards, April, 1994, unless otherwise noted.

4 - Oral Slope Factor. Values in this column were obtained from US EPA's *Integrated Risk Information System (IRIS)* database.

5 - Inhalation Unit Risk. Values in this column were obtained from IRIS unless otherwise noted.

- 6 - This value is referenced in Table 2 of HEAST, as an adequate provisional value.
- 7 - Not Available.
- 8 - This value was obtained from IRIS.
- 9 - This value has been **withdrawn** from HEAST.
- 10 - This value was developed for the *Residential Shortform* (MADEP/Office of Research and Standards).
- 11 - This value was obtained from HEAST.
- 12 - This value was obtained from MADEP/Office of Research and Standards.
- 13 - This cancer soil ingestion RAF was obtained from *Background Documentation for the Development of the MCP Numerical Standards*, MADEP/Bureau of Waste Site Cleanup and Office of Research and Standards, April, 1994.
- 14 - Total Petroleum Hydrocarbons. Assuming that volatile fractions were not present, toxicity values for Naphthalene were used as conservative surrogates for TPH.

**TABLE 2: EXPOSURE PARAMETERS**

Exposure Parameters	1-2 Year Old Child
Ventilation Rate (VR) for Light Exertion	3 liters per minute <sup>1</sup>
Body Weight (BW) for Females	10.8 kilograms <sup>2</sup>
Averaging Period (AP) for Non-Cancer Equations	1 year
Averaging Period (AP) for Cancer Equations	70 years
Exposure Frequency (EF)	1 event per day
Exposure Duration (ED)	24 hours per day
Exposure Period (EP)	1 year

1 - This value was obtained from Table B-4 of the *Guidance For Disposal Site Risk Characterization In Support of the Massachusetts Contingency Plan*, MADEP/Bureau of Waste Site Cleanup and Office of Research and Standards, July, 1995 (Interim Final Policy BWSC/ORS-95-141).

2 - This value was obtained from Table B-1 of the above referenced document.

**APPENDIX C -  
REFERENCES FOR APPROACH USED TO ESTIMATE  
FATE OF INHALED PARTICLES**

**REFERENCES/CITATIONS FOR APPROACH USED  
TO ESTIMATE FATE OF INHALED PARTICLES:**

*Methodology for Relating Soil Contaminant Levels and Risk to Human Health*, MADEP/Office of Research and Standards, March, 1997.

*Sullivan's Ledge Superfund Site: Derivation of Ambient Air Particulate Exposure Limits for Remediation Activities*, Internal MADEP Memorandum from Diane Manganaro and Tsedash Zewdie, ORS, to Charles Tuttle, BWSC, September 20, 1994.

*Summary of Interim Procedures and Assumptions Used in Relating Soil Contaminant Levels and Risk to Human Health*, MADEP/Office of Research and Standards, June, 1993.

*Comparison of Landfill Soil Cover Criteria to Soil Levels Derived Using Risk Assessment Methodology*, MADEP/Office of Research and Standards, August, 1992.