Massachusetts Department of ENVIRONMENTAL PROTECTION

t e c h n i c a l u p d a t e

Characterization of Risks Due to Inhalation of Particulates by Construction Workers

Revised July 2008
Update to: Section 7.3 and Appendix B of the MA DEP *Guidance for Disposal Site Risk Characterization – In Support of the Massachusetts Contingency Plan* (1995).

Introduction

Inhalation of airborne particulate matter from contaminated soil is a potentially significant exposure pathway at any site where construction activities involve excavation of soil or movement of vehicles and heavy equipment over soil. MassDEP has quantitatively compared risks associated with enhanced incidental ingestion of soil and those associated with inhalation of respirable particulates, assuming an equal concentration of OHM in both media. The results of this analysis clearly demonstrated that, for a number of chemicals in the utility/heavy construction worker scenario, risks associated with inhalation of respirable particulates contribute to a significant portion of total risk. Accordingly, risk assessments done for disposal sites with contaminated soil where construction projects may be undertaken should include a quantitative evaluation of exposures and risks from inhalation particulates originating from the soil.

This Technical Update is a revision of the update original published in 2002. Two significant changes are made by this revision:

(1) The assumed percentage of total respirable particulate matter that falls in the size range of 10 microns and below is revised from 40% to 50% to be consistent with previous ORS guidance and practice (ORS 1994). This change will result in lower estimates of risk from inhaled particles that are swallowed at a given PM10 concentration.

(2) The descriptions of the dose and risk calculations are revised to provide clearer guidance and documentation. This is simply a change in the arrangement of the equations. For a given PM10 concentration, the numerical value risk estimate does not change.

Assessment of Risk to Construction Workers from Inhaled Particles

General Background

MassDEP's 1995 Guidance for Disposal Site Risk Characterization presents particulate exposure estimation methods in Section 7.3. In that section, the Guidance recommends evaluating particulate exposures as doses. (In contrast, vapor exposures are evaluated as concentrations.) It does not, however, fully describe a method to account for the two exposure routes associated with inhalation of airborne particulates.

The risk assessment approach presented in this Technical Update considers exposure and risk from contaminants adsorbed to particles that are swallowed and reach the GI tract as well as contaminants on particles deposited in the lungs.

The exposure routes of concern are:

(1) Absorption of contaminants in the gastrointestinal (GI) tract following coughing up and subsequent swallowing of particulates trapped by the mucosa of the upper respiratory tract and

(2) Absorption of contaminants from the respiratory system following inhalation into the lungs.

Guidance for assessing both of these pathways is provided in other ORS documents and memoranda (MassDEP 1997; ORS 1994 [Attachment A]; Weidner et al.).

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Dose-Response Assessment

Since inhalation of particulate matter involves two exposure routes, pulmonary and gastrointestinal, dose-response information specific to each of these routes is used in the risk assessment. To characterize risk from particles that are swallowed, oral reference doses (RfDs) and oral cancer slope factors (CSFs) should be used with the estimated gastrointestinal doses. To characterize risk from particles that reach and remain in the lungs, inhalation RfDs and CSFs should be used with the estimated pulmonary doses. While oral RfDs and CSFs are published on EPA's IRIS Database, inhalation RfDs and CSFs are not.

EPA publishes cancer and non-cancer inhalation toxicity values as unit risk factors (URFs) in units of $(\mu g/m^3)^{-1}$ and reference concentrations (RfCs) in units of mg/m^3 respectively. These toxicity values correspond to exposure concentrations, and are mainly used to evaluate risks from concentrations of volatile and semi-volatile organic compounds present as vapors in air.

To evaluate risks from doses of contaminants that are deposited in the lung with inhaled particulates in accordance with MassDEP guidance, toxicity values that correspond to exposure doses (not concentrations) are called for. Thus, RfCs must be converted to RfDs and URFs to CSFs. For these conversions, ORS recommends using EPA default exposure factors of 20 m^3 per day respiration rate and 70 kg body weight. These factors have been used by EPA for allometric adjustments in deriving the RfCs (U.S. EPA 1994). The conversion equations are:

$$RfD_{inhalation} = RfC \times 20\ m^3 \text{ per day} / 70\ kg$$

$$CSF_{inhalation} = URF \times 1000\ \mu g/mg \times 70kg / 20\ m^3 \text{ per day}$$

The inhalation and oral RfDs are used with average daily doses (ADDs) of contaminants adsorbed to particles to calculate non-cancer health risk. The inhalation and oral CSFs are used with the lifetime average daily doses (LADDs) to assess cancer risk. Risk characterization is discussed in more detail in a subsequent section.

Exposure Assessments

To calculate the exposure associated with these two uptake pathways, DEP assumes the following for the construction worker scenario:

- 100% of respirable particulate mass is equal to or less than 30 microns in diameter (≤ PM-30) (ORS 1994, MassDEP 1997)
- 50% of total respiratory particulate mass is equal to or less than 10 microns in diameter (≤ PM-10) (ORS 1994; Weidner et al.; ORS 2006).
- 100% of inhaled particulates greater than 10 microns but less than or equal to 30 microns are swallowed (ORS 1994).
- 50% of inhaled particulates equal to or less than 10 microns are swallowed, and the remaining 50% enter the lungs (MassDEP, 1997)

Based on these assumptions, the effective exposure concentration of respirable particulates for the GI system is 1.5 times the concentration of PM-10, while that for the lungs is 0.5 times the concentration of PM-10. Using these effective exposure concentrations, OHM average daily doses for the GI and respiratory systems can be estimated using modified versions of equations 7-18 in the Guidance. The two equations that follow are used to estimate (1) the dose receiveved from inhaled particles that are swallowed and move into the GI tract and (2) the dose from particles that reach the lung.

(Lifetime) Average Daily Dose for the GI System ((L)ADD$_{inhal\text{-}GI}$)

$$ADD_{inhal-GI} = \frac{[OHM_{particulate}] \times 1.5 \times [PM_{10}] \times Inh \times RAF \times EF \times ED \times EP \times C1 \times C2 \times C3}{BW \times AP}$$

where:

$ADD_{inhal\text{-}GI}$ =	Average daily dose due to coughing up and subsequent ingestion of inhaled particulates; expressed in mg/kg-day
$[OHM_{particulate}]$ =	Concentration of oil/hazardous material in airborne particulates; expressed in mg/kg
$[PM_{10}]$ =	Concentration in air of particulates less than or equal to 10 microns in diameter; expressed in $\mu g/m^3$
Inh =	Inhalation rate for the receptor of concern during the period of exposure; expressed in l/min
RAF_{oral} =	Relative Absorption Factor for the GI exposure route; dimensionless
EF =	Number of exposure events during the exposure period divided by the number of days in the exposure period; expressed as events/day since the same exposure occurs every week of the exposure period, exposure 5 days per 7 days is used to represent events/day
ED =	Duration of each exposure event; expressed as hours/event
EP =	Duration of the exposure period; expressed as days
BW =	Body weight of the receptor of concern during the averaging period; expressed as kg
AP =	Averaging period; expressed as days
C1 =	Unit conversion factor for mass; 10^{-9} kg/μg
C2 =	Unit conversion factor for volume; $10^{-3}m^3$/l
C3 =	Unit conversion factor for time; 60 min/hour

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(Lifetime) Average Daily Dose for the Respiratory System ((L)ADD_{inhal})

$$(L)ADD_{inhal} = \frac{[OHM_{particulate}] \times 0.5 \times [PM_{10}] \times Inh \times RAF \times EF \times ED \times EP \times C1 \times C2 \times C3}{BW \times AP}$$

where:

(L)ADD_{inhal} =	Average daily dose due to inhaled particulates entering the lungs; expressed in mg/kg-day
[$OHM_{particulate}$] =	Concentration of oil/hazardous material in airborne particulates; expressed in mg/kg
[PM_{10}] =	Concentration in air of particulates less than 10 microns in diameter; expressed in $\mu g/m^3$
Inh =	Inhalation rate for the receptor of concern during the period of exposure; expressed in l/min
RAF_{inhal} =	Relative Absorption Factor for contaminants on particles deposited in the lung; dimensionless
EF =	Number of exposure events during the exposure period divided by the number of days in the exposure period; expressed in events/day - since the same exposure occurs every week of the exposure period, exposure 5 days per 7 days is used to represent events/day
ED =	Duration of each exposure event; expressed in hours/event
EP =	Duration of the exposure period; expressed in days
BW =	Body weight of the receptor of concern during the averaging period; expressed in kg
AP =	Averaging period; expressed in days
C1 =	Unit conversion factor for mass; 10^{-9} kg/μg
C2 =	Unit conversion factor for volume; $10^{-3} m^3/l$
C3 =	Unit conversion factor for time; 60 min/hour

DEP Recommended Default Values

For the equations above, DEP recommends the following default measurement units and values:

[$OHM_{particulate}$] =	site-specific; expressed as mg/kg
[PM_{10}] =	60 $\mu g/m^3$ (Appendix B, MassDEP 1995).
Inh =	60 l/min Ventilation rate for heavy exertion. (Appendix B, MassDEP 1996).
RAF =	chemical-specific; dimensionless
EF =	.714 event/day (5 days per week, Appendix B, MassDEP 1995)
ED =	.333 day/event (8 hours per event, Appendix B, MassDEP 1995)
EP =	182 days (Appendix B, MassDEP 1995)
BW =	58 kg (50^{th} percentile of female body weights, ages 18-24, Table 7-5, Appendix B, U.S. EPA ,1997)
AP =	182 days for noncancer risk; 25,550 days for cancer risk (Appendix B, Guidance)
Inh_{day} =	20 m^3/day

The default value of 60 $\mu g/m^3$ for [PM_{10}] presented in the Guidance was based on data collected from non-construction sites. In light of a 1998 report on PM_{10} concentrations near construction sites for the Central Artery Tunnel Project

(Massachusetts Highway Department), DEP re-evaluated the appropriateness of the 60 µg/m^3 default value. The Highway Department report presents data on PM_{10} concentrations obtained June through October, 1997, at 12 locations along the Central Artery. Samples were obtained between 30 and 300 feet outside construction fence lines. One sampling location (Site 11) was situated near the Subaru Pier stockpile facility. During the sampling period, over 1,200 dump trucks per day visited the facility to deposit excavated material. Therefore, DEP did not consider results from this location because such a high truck volume is not representative of most construction sites.

The arithmetic means of PM_{10} concentrations for the remaining 11 locations ranged from 30 to 77 µg/m^3, while the arithmetic mean of these values (i.e., the mean of the means) was 53 µg/m^3. While these values (range of means and mean of means) are not direct measurements of fugitive dust at construction sites, they do suggest that a PM_{10} concentration of 60 µg/m^3 for such sites is reasonable.

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Risk Characterization

The $ADD_{inhalation\text{-}GI}$ and the $ADD_{inhalation}$ calculated above can be used with inhalation and oral reference doses respectively to characterize noncancer risks to a construction worker inhaling airborne particulates containing the OHM. Noncancer risks due to GI and respiratory system uptake of inhaled particulates can be calculated as follows:

$$HI_{Inhalation} = \left(\frac{ADD_{inhalation-GI}}{RfD_{oral}} \right) + \left(\frac{ADD_{inhalation}}{RfD_{inhalation}} \right)$$

Where:

$HI_{Inhalation}$	=	The Hazard Index associated with exposure to the chemical following inhalation of chemical-containing airborne particulates; dimensionless
$ADD_{inhalation\text{-}GI}$	=	Average daily dose due to coughing up and subsequent ingestion of inhaled particulates; expressed in mg/kg-day
RfD_{oral}	=	The oral reference dose or appropriate substitute toxicity value identified for the chemical; expressed in mg/kg-day
$ADD_{inhalation}$	=	Average daily dose a receptor receives from particles deposited in the lung; expressed in mg/kg-day
$RfD_{inhalation}$	=	The inhalation reference dose; obtained from the published inhalation reference concentration; expressed in mg/kg-day

Lifetime average daily doses (LADDs) of chemicals adsorbed to particulate matter are used with cancer slope factors to characterize cancer risk. Excess lifetime cancer risks due to GI and respiratory system uptake of inhaled particulates can be calculated as follows:

$$ELCR_{particulate} = \left(LADD_{inhalation-GI} \times CSF_{oral}\right) + \left(ADD_{inhalation} \times CSF_{inhalation}\right)$$

where,

$ELCR_{particulate}$ = The excess lifetime cancer risk associated with exposure to the chemical following inhalation of chemical-containing airborne particulates; dimensionless

$LADD_{inhalation\text{-}GI}$ = Lifetime average daily dose due to coughing up and subsequent ingestion of inhaled particulates; expressed in mg/kg-day

CSF_{oral} = The oral cancer slope factor identified for the chemical; expressed in mg/kg-day

$LADD_{inhalation}$ = Average daily concentration to which a receptor is exposed; expressed in mg/m^3

$CSF_{inhalation}$ = The inhalation cancer slope factor, derived from the published unit risk factor (URF); expressed in $(mg/kg\text{-}day)^{-1}$

Limitations

The approach outlined in this Technical Update has some limitations that should be noted:

- The approach presented in this Technical Update only evaluates exposure to contaminants adsorbed to particulates. Risks for construction workers from exposure to volatile organic compounds (and some semi-volatile organic compounds) present as vapors in air must be evaluated separately.
- The PM_{10} multiple of 1.5 used to estimate the amount of particulate matter ingested is recommended for construction workers only. For other exposure scenarios, such as residential exposure to particulate matter originating from a nearby site, a multiple of 2 is recommended (ORS 1994).

Further Information

For further information about this Technical Update, please contact Nancy Bettinger, Massachusetts Department of Environmental Protection, One Winter Street, Boston, MA 02108, telephone: (617) 292-5841, email: Nancy.Bettinger@state.ma.us.

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References

MassDEP 1995. *Guidance for disposal site risk characterization.* Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards. Interim Final Policy. BWSC/ORS-95-141.

MassDEP 1997. *Methodology for relating soil contaminant levels and risk to human health.* Massachusetts Department of Environmental Protection, Office of Research and Standards. Section 6.1.4.

Massachusetts Highway Department. 1998. Central Artery (I-93)/Tunnel (I-90) Project: Particulate Matter (PM_{10}) Monitoring and Field Inspection Program for Mainline Construction (June through October, 1997). July 1998.

ORS 1994. ORS Memorandum to BWSC: Sullivan's Ledge Superfund Site: Derivation of Ambient Air Particulate Exposure Limits for Remediation Activities. September 20, 1994.

ORS 2006. *Explanation of Assumptions Used to Assess Particulate Inhalation Exposures of Construction Workers*. October 2006.

U.S. EPA 1994. *Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry*. Environmental Criteria and Assessment, Office of Health and Environmental Asssessment, Office fo Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. October 1994. EPA/600/8-90/066F.

U.S. EPA 1997. *Exposure Factors Handbook. Volume 1*. Office of Research and Development. EPA/600/P-95/002Fa. August 1997.

Weidner, C., J. Fitzgerald and M. Vallarini. Real-Time Air Monitoring at Construction and Remediation Sites to Estimate Risks of Contaminated Dust Migration. Paper presented at the 12th Annual Conference on Contaminated Soils, University of Massachusetts at Amherst. Massachusetts Department of Environmental Protection. October 1997.

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