MCP Method 2 Risk Characterizations

MassDEP & LSPA Training Seminars

Fall 2005

MassDEP

Introduction & Overview

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Schedule for the Day

Time	Topic	Presenter
9:00 – 9:10	Introduction & Overview	Paul Locke
9:10 – 10:45	Regulatory Framework	
	Deriving New M2 Standards	
	Leaching, Infiltration, Transport & Discharge	
10:45-11:00	Break	
11:00-12:00	Real World Examples	Janet Keating Connolly
12:00-1:00	Risk Assessment ShortForm	Andrew Friedmann

Regulatory Framework: What's Allowed, What Isn't & Why

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Regulatory Framework

- 310 CMR40.0941
  Approaches to Characterizing Risk of Harm
- 301 CMR 40.0942
  Selection of Method to Characterize the Risk of Harm to Health, Public Welfare and the Environment
- 310 CMR 40.0980
  Method 2 Risk Characterization

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310 CMR40.0941

Approaches to Characterizing Risk of Harm

1. Imminent Hazards, Substantial Hazards and Safety Hazards evaluated separately;
2. Method 1, 2 and/or 3 used to evaluate risk of harm to health, public welfare and the environment;
3. Method used depends on nature of risks, response action and site.

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310 CMR 40.0942

Selection of Method

- Methods designed to provide roughly equivalent level of protection, as measured by *Cumulative Receptor Risk*

  310 CMR 40.0902(2)(a)

- Method 2 is never *required*

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310 CMR 40.0942

Selection of Method

- Method 2 alone can be used if contamination limited to soil & groundwater [like M1, see 40.0942(2)]

- A risk characterization using *both* Method 1 and Method 2 values is considered a "Method 2" (for bookkeeping purposes).

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310 CMR 40.0942

Selection of Method

- A *combined* Method 2 and Method 3 is possible, if:
  - Method 2 can address all human health risk in soil, groundwater and possibly sediment, and
  - Method 3 is used only for ecological risk

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310 CMR 40.0942

Selection of Method

"and possibly sediment" ?

- **Yes**, see MCP Master Q&A, page 70, where DEP clarifies an instance in which "sediment" can be considered "soil" to simplify the risk characterization

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310 CMR 40.0980

Method 2 Risk Characterization: What CAN Be Done

- Groundwater and Soil Standards Developed for chemicals without Method 1 Standards
- Site-Specific Conditions used to modify the leaching component of the Method 1 Soil Standards, or show the contaminant will not leach

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310 CMR 40.0980

Method 2 Risk Characterization: What CAN Be Done

- Site-Specific Conditions used to modify the vapor infiltration component of the Method 1 GW-2 Groundwater Standards, or show an incomplete pathway
- Site-Specific Conditions used to modify the groundwater transport component of the Method 1 GW-3 Groundwater Standards, or show no discharge will occur

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310 CMR 40.0980

Method 2 Risk Characterization: What CAN Be Done

- Any Combination of the Above Items

For Example:

You CAN create a new soil standard for a chemical without a Method 1 value AND apply site-specific leaching criteria.

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310 CMR 40.0980

Method 2 Risk Characterization: What CANNOT Be Done

- Cannot modify Method 1 GW-1 Standards. Ever.
- Cannot modify the risk assessment aspects of the Method 1 Standards (e.g., exposure frequency, body weight, toxicity values)

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310 CMR 40.0980

Method 2 Risk Characterization: What CANNOT Be Done

- Cannot increase the Soil Standards beyond the values listed in Table 5 for Direct Contact Exposures
- Cannot increase the GW-2 or GW-3 standards beyond the Upper Concentration Limits listed in Table 6

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310 CMR 40.0980

Other Considerations

- Method 2 Standards are used like Method 1 Standards
  - E.g., rules for averaging apply
- The MCP Method 2 Standards developed and used or relied upon by the LSP shall be listed and suitably documented. (40.0982(6))
  - Include equations, input parameters, modeling assumptions and cite sources.

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310 CMR 40.0980

Other Considerations

- MassDEP-derived and published Method 2 Standards (310 CMR 40.0982(7))
  - Useable like Method 1 Standards
  - Used at the PRP's/LSP's option

Example:

- "Final" Method 1 Standards before their effective date. MassDEP will publish (on web) values and invoke this rule

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OPTION

(i.e. WAIT 2 ADOPTION)

Deriving New Method 2 Standards: Equations and References

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Deriving "New" Method 2 Standards

Replicating the Method 1 Standard Development Process

- Regulations specify step-by-step process in 40.0983 (groundwater) and 40.0984 (soil)
- Specified equations incorporate default exposure assumptions which cannot be modified

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Deriving "New" Method 2 Standards

Replicating the Method 1 Standard Development Process

- Specified equations incorporate default fate & transport (volatilization, migrations, leaching) assumptions
- Fate and transport considerations can subsequently be modified on a site-by-site basis (40.0985 through 40.0987)
- For ease-of-use, these two steps can be combined into one calculation

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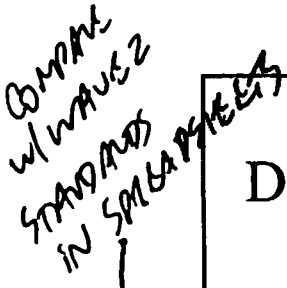

Deriving "New" Method 2 Standards

Replicating the Method 1 Standard Development Process

- Helpful references:
  - *"Background Documentation for the Development of the MCP Numerical Standards" (1994)*
  - *"Guidance for Disposal Site Risk Characterization"* (1996)
- Documentation and equations will be updated to reflect "Wave 2" changes, but the basic process will remain the same
- See also derivation of standards on web at http://Mass.Gov/dep/bwsc/files/standard/standard.htm

MOST HELPFUL

TEMPORARY (UNTIL END OF '05?)

MassDEP

Deriving "New" Method 2 Standards

Replicating the Method 1 Standard Development Process

Common Factors:

- RfD = Reference Dose, a measure of non-cancer toxicity. Units: mg/(kg*day)
- CSF = Cancer Slope Factor, a measure of carcinogenicity (oral). Units: $(mg/(kg*day))^{-1}$
- UR = Unit Risk, a measure of carcinogenicity (inhalation). Units: $(\mu g/m^3)^{-1}$
- Start looking for these values at MassDEP (http://Mass.Gov/dep/ors/orspubs.htm) or USEPA (http://www.epa.gov/iriswebp/iris/index.html)

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Deriving "New" Method 2 Standards

Replicating the Method 1 Standard Development Process

Common Factors:

- RAF = Relative Absorption Factor
  (unitless)
  Can be set = 1 for a generally conservative default,
  Described in MassDEP Risk Assessment Guidance
- OHM = Acronym for "Oil or Hazardous Material"

MassDEP

Creating GW-1 Standards

40.0983(2)

- GW-1 Standards are based on the protection of groundwater for either its current or future use as drinking water
- Standard exposure assumptions assume a lifetime of drinking water at a rate of 2 liters/day.
- Assumptions consistent with methods for setting USEPA and MassDEP Maximum Contaminant Levels (MCLs)

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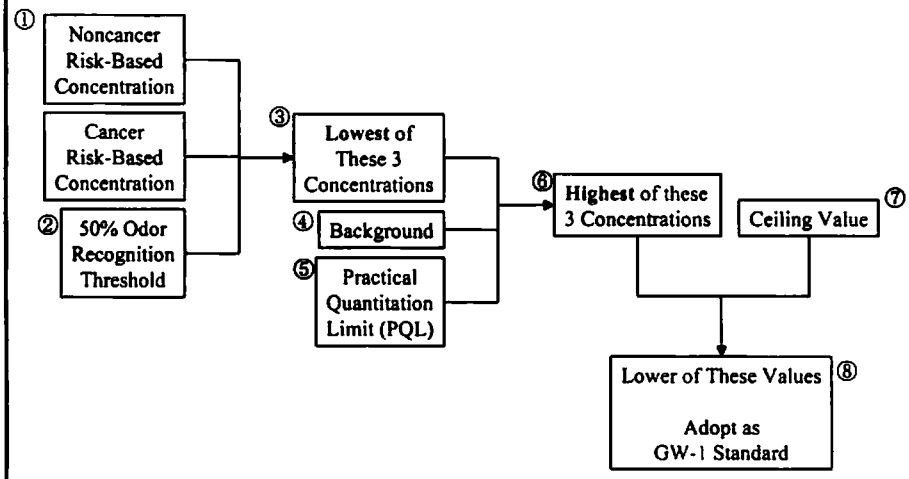
Groundwater GW-1 Standards



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Creating GW-1 Standards

40.0983(2)

- Non-Cancer Risk-Based Level:

$$[OHM] = \frac{(RfD \times 7{,}000)}{RAF_{oral}}$$

- 7,000 = Exposure Factors:

$$\frac{(Hazard\ Index \times Body\ Weight \times Conversion)}{Water\ Intake}$$

$$7{,}000\ \frac{(kg \cdot \mu g \cdot day)}{(mg \cdot Liters)} = \frac{\left(0.2 \times 70\ kg \times 1{,}000\ \frac{\mu g}{mg}\right)}{2\ \frac{Liters}{day}}$$

MassDEP

Creating GW-1 Standards

40.0983(2)

- ***Always*** check units:

$$[OHM] = \frac{(RfD \times 7{,}000)}{RAF_{oral}}$$

$$\frac{\mu g}{Liter} = \frac{\left(\frac{mg}{(kg \cdot day)} \times \frac{(kg \cdot \mu g \cdot day)}{(mg \cdot Liters)}\right)}{1}$$

MassDEP

Creating GW-1 Standards

40.0983(2)

- Cancer Risk-Based Level:

$$[OHM] = 0.35 / (CSF \times RAF_{oral})$$

- 0.035 = Exposure Factors:

$$(Cancer\ Risk\ Limit \times Body\ Weight \times Conversion) / Water\ Intake$$

$$0.035\ {}^{(kg \cdot \mu g \cdot day)}/_{(mg \cdot Liters)} = \left(10^{-6} \times 70\ kg \times 1{,}000\ {}^{\mu g}/_{mg}\right) / 2\ {}^{Liters}/_{day}$$

1 IN A MILLION

MassDEP

Creating GW-1 Standards

40.0983(2)

Odor Recognition Threshold

- Concentration in water that 50% of population can detect
- An objective measure of organoleptic

  (or·gan·o·lep·tic _ (ôr g -n -l p t k, ôr-g n -)

  effects – taste and odor – that can indicate a risk to Public Welfare

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Creating GW-1 Standards

40.0983(2)

Examples:

1. 2-ethyl-4-methyl-1,3-dioxolane (2-EMD) has a distinctive sweet odor described as "sickening sweet" or "medicinal sweet", with an odor threshold concentration of between 5 and 10 ng/l.
2. Using a panel of 57 consumers, a study yielded the 15 µg/L threshold for MTBE, which was the geometric mean of the individual thresholds for each of the 57 consumer panelists.

MassDEP

Creating GW-1 Standards

40.0983(2)

Background Levels

- Site-specific background level in groundwater determined for the site
- See Risk Assessment Guidance, chapter 2, for background discussion
- Average (arithmetic average) site-specific value is appropriate

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TOLUENE HAS A LOW TOXICITY

Creating GW-1 Standards

40.0983(2)

Practical Quantitation Limit

- Method 2 Standards should be measurable
- An appropriately sensitive analytical method should be identified – as close to the risk-based levels as feasible
- "Method Detection Limit" or MDL not appropriate: values around the MDL are not reliably quantified

MassDEP

Creating GW-1 Standards

40.0983(2)

Ceiling Levels

- Ceiling level is a cap (50,000 µg/L) on how high the calculated risk-based value can be set on a generic basis
- In regulations application of ceiling value occurs at 310 MR 40.0983(5) – after the methodology for all 3 GW standards

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Creating GW-2 Standards

40.0983(3)

- Based on the infiltration of vapors into a building from a contaminated groundwater source.
- Exposure assumed to occur on a daily basis over a lifetime
- Methodology roughly similar to other states (CT) and USEPA VI guidance

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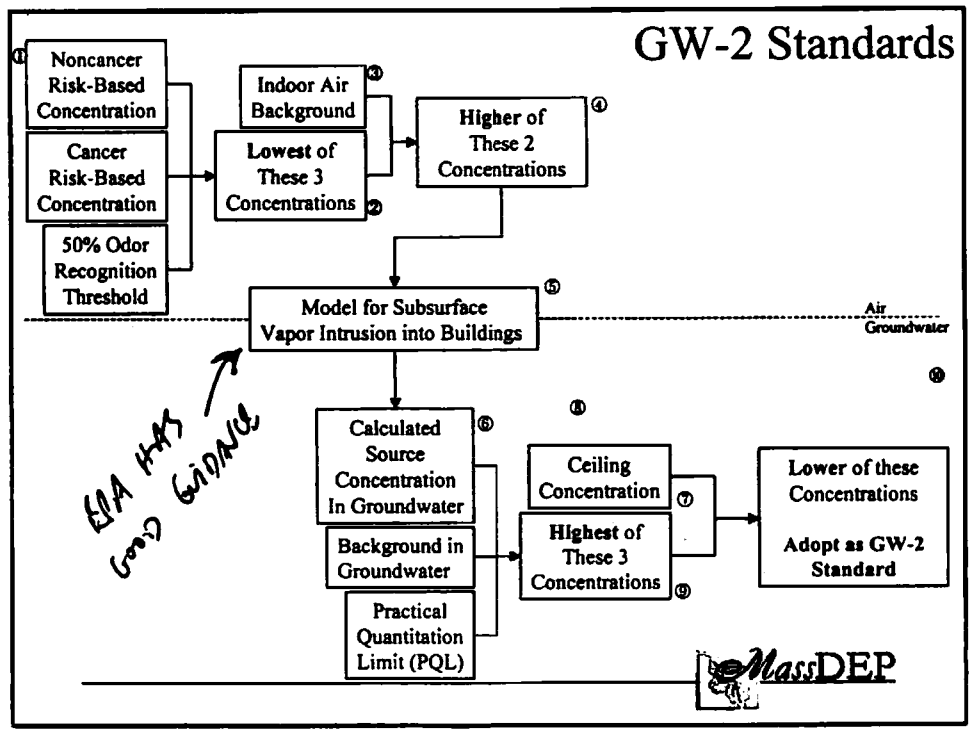

EPA VAPOR INTRUSION GUIDANCE

Creating GW-2 Standards

40.0983(3)

- Non-cancer Risk Equation: $[OHM]_{air} = 0.2 \times RfC$
- Cancer Risk Equations: $[OHM]_{air} = 10^{-6} / UR_{air}$
- 50% Odor Threshold *in air*

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Creating GW-2 Standards

40.0983(3)

Indoor Air Background

- Regulations do *not* specify "site-specific"
- See Discussions:
  - Guidance for Disposal Site Risk Characterization
    Policy #95-141, Section 2.3 (page 2-25)
  - Indoor Air Sampling and Evaluation Guide, WSC
    Policy #02-430, Section 5.9 (page 56)

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* USE GENERIC DATABASES

Creating GW-2 Standards

40.0983(3)

Vapor Intrusion Model

- Equation in Regulation (40.0983(c)):

$$[OHM]_{gw} = [OHM]_{air} / (\alpha \times d \times H * C)$$

$$[OHM]_{gw}\,{}^{ug}/_{Liter} = [OHM]_{air}\,{}^{ug}/_{m^3} / (0.0005 \times 0.1 \times H * 1{,}000\,{}^{Liters}/_{m^3})$$

- H = dimensionless form of Henry's Law Constant

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Creating GW-3 Standards

40.0983(4)

- Based on the potential ecological risk posed by a discharge of contaminated groundwater to a surface water body
- Assumes minimal dilution during groundwater transport and discharge
- Assumes ecological receptors in receiving water body

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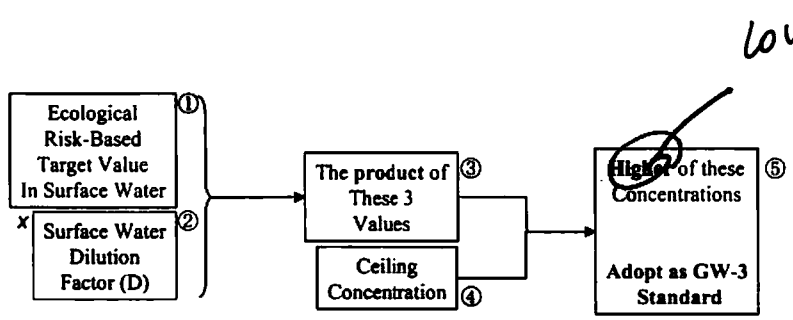
GW-3 Standards



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Creating GW-3 Standards

40.0983(4)

Target Ecological Risk-Based Concentration

- Regulations specify (USEPA) Water Quality Criteria or "analogous value"
- MassDEP has described a hierarchy of "analogous values"

(See documentation of proposed GW-3 values)

MassDEP

lowest observed effect level (LOEL)

Creating GW-3 Standards

40.0983(4)

- Hierarchy:
  - National Recommended Water Quality Criteria
    (chronic preferred to acute)
  - LOEC, EC_{50} or LC_{50} from literature
    (see USEPA's AQUIRE database)
  - Suter and Tsao (1996)
  - Other literature sources

Acute values are divided by factor of 10 to estimate chronic value

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Creating GW-3 Standards

40.0983(4)

Surface Water Dilution Factor

- Set to 10 as estimate of dilution as groundwater discharges to a low-flow stream
- Based on minimal dilution factored into surface water discharge permits

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Creating Soil Standards

40.0984

- Methodology for S-1, S-2 and S-3 Soil Standards is the same, just the exposure factors differ
- Ceiling Concentrations also vary by soil category and chemical-specific factors

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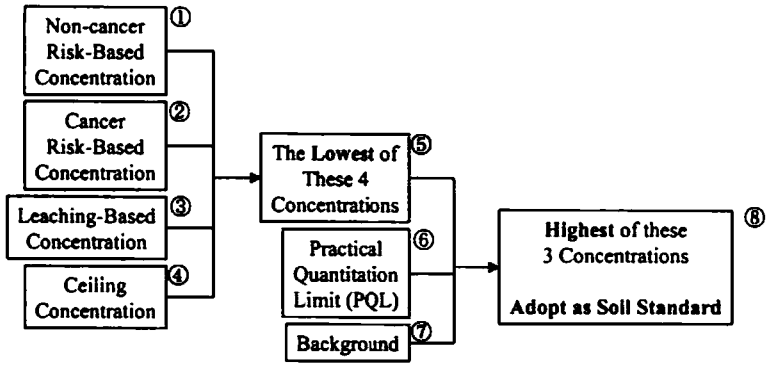
Soil Standards



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Creating Soil Standards

40.0984

- Non-Cancer Risk Equation:

$$[OHM] = \left(RfD \times 0.2 \times 10^{6\ mg/kg}\right) \Big/ \left((RAF_{oral} \times OEF) + (RAF_{dermal} \times DEF)\right)$$

- Cancer Risk Equation:

$$[OHM] = \left(10^{-6} \times 10^{6\ mg/kg}\right) \Big/ \left(CSF \times (RAF_{oral} \times OEF) + (RAF_{dermal} \times DEF)\right)$$

OEF = "oral exposure factor"

DEF = "dermal exposure factor"

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Creating Soil Standards

40.0984

Non-Cancer Risk Exposure Factors

$mg_{soil}/(kg_{body\ weight} * day)$

	Oral Exposure Factor	Dermal Exposure Factor
S-1	3.1	28.5
S-2	0.29	15.2
S-3	0.63	32.5

MassDEP

Creating Soil Standards

40.0984

Cancer Risk Exposure Factors

$mg_{soil}/(kg_{body\ weight} * day)$

	Oral Exposure Factor	Dermal Exposure Factor
S-1	0.41	7.3
S-2	0.11	5.48
S-3	0.029	1.5

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Creating Soil Standards

40.0984

Basis for Oral and Dermal Exposure Factors

- Described in "*Background Documentation...*", appendices A, B & C
- Year-by-Year Average Daily Soil Intake and Dermal Contact Rates
- Excessively complex. Wave 2 process greatly simplified and transparent

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Creating Soil Standards

40.0984

Leaching-Based Value

- Must consider applicable Groundwater Standards at the site (*Hint: Create the groundwater standards first.*)
- 40.0984(4) refers to 40.0985 – giving site-specific flexibility to develop leaching-based number
- Continue in process for *each* soil/groundwater category combination

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Creating Soil Standards

40.0984

Soil Ceiling Concentrations

- Different values by both soil category and chemical characteristics
- Public Welfare concerns: "Odor Index" approach:

  Odor Index = Vapor Pressure x Odor $\text{Threshold}_{50\%}$
- Greater "Odor Index" the lower the ceiling

MassDEP

NO NSDD for Fruit or Vegetable pathways

Creating Soil Standards

40.0984

Ceiling Values (mg/kg)

i.e. METALS

	High Odor Index	Medium Odor Index	Low Odor Index
S-1	100	500	1,000
S-2	500	1,000	2,500
S-3	1,000	2,500	5,000

MassDEP

i.e. VOCs

Creating Soil Standards

40.0984

Soil Background Concentrations

- Regulations specify a site-specific background level (40.0984(1))
- See Risk Assessment Guidance, chapter 2, for background discussion
- Average (arithmetic average) site-specific value is appropriate

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Modeling Leaching, Vapor Infiltration and Groundwater Transport

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Leaching

40.0985

- Modify Method 1 (or 2) standards based on site-specific leaching considerations
  - Develop an alternative leaching-based soil concentration
  - Demonstrate that leaching is not a concern at the site
  - Use modeling of source mass and subsurface hydrogeological conditions
  - Use leaching tests

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i.e. PARTNER @ SITE ; SOIL STATES

Leaching

40.0985

What is the current Method 1 standard based on?

Will modifying the leaching component significantly change the outcome?

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Leaching

40.0985

- Method 2 changes to the soil standards limited by the Direct Contact Risk-Based values listed in Table 5
- If the Method 1 Standard is equal to or close to the Table 5 value, *Ça ne vaut pas la peine.* (Not worth the pain)

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Leaching

40.0985

1993 DEP used a simple modification of an Oregon DEQ model:

- 3-meter thick unsaturated zone, divided into three 1-meter layers.
- Contamination in the middle layer
- Contamination uniformly distributed over a 10 m x 10 m area.
- Unsaturated zone and aquifer are sandy soil with uniform properties.
- Upper and lower unsaturated zone layers are initially clean, as is the aquifer.

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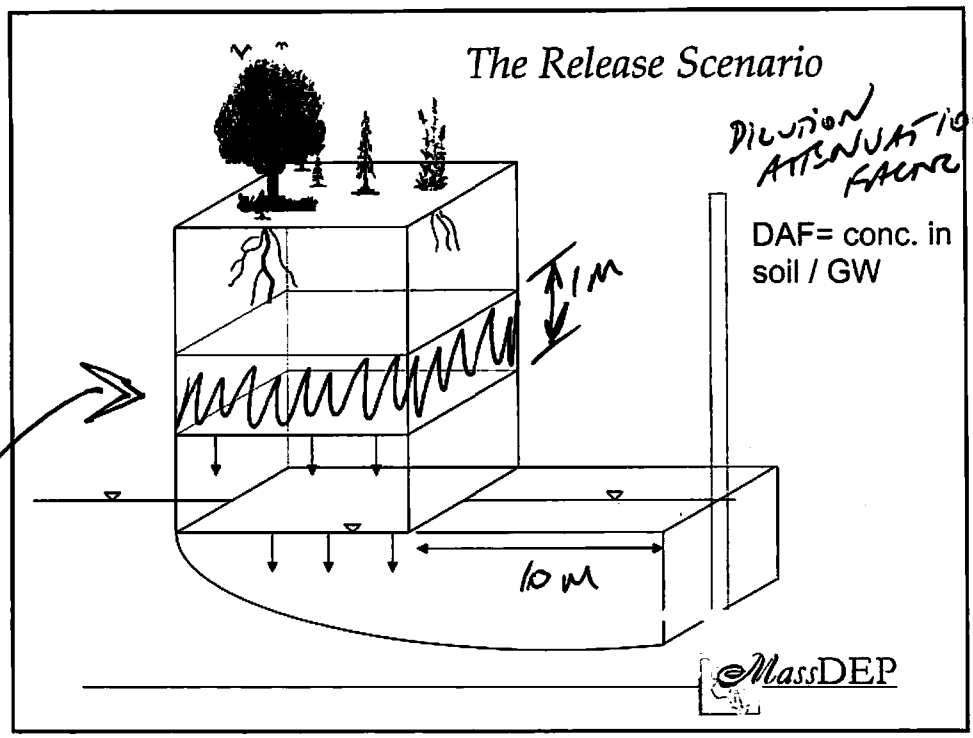

Leaching

40.0985

- Eight chemicals run through SESOIL/AT123D model to develop regression equation then applied to remaining Method 1 chemicals:

$$DAF = 6207 * H + 0.166 * Koc$$

- This equation can be used as a simple first cut (for new standards), but…
  - MassDEP discovered flaws in Oregon's model
  - Site-specific data needed for *adjusting* Method 1 stnds

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Leaching

40.0985

Sensitivity Analysis

- Distance to a receptor in Y-axis (Most sensitive)
- Hydraulic conductivity
- Thickness of the upper layer of the soil column
- Thickness of the layer above the saturated zone
- Regional climate of MA
- Bulk density (Least sensitive)

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Leaching

40.0985

Examples of Massachusetts-Specific Input Data/Distributions

- Bulk density: Point value, 1.6 g/cc
- Effective porosity: Uniform distribution, 0.25 - 0.35
- Hydraulic gradient: Logarithmic distribution, mean= -4.53, S.D.=1.08
- Hydraulic gradient arithmetic space: mean= 0.01, lower limit = 0.0015, upper limit = 0.03

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Leaching

40.0985

Range of Results using Mass-Specific Data Using SESOIL/AT123d

Carbon Tetrachloride (DAF)

85%	90%	95%	1993 DAF	MCP GW-1 Std., mg/l
3,627	1,441	513	200	0.005

Carbon Tetrachloride (Soil Cleanup Numbers, mg/kg):

85%	90%	95%	Current leaching Std.(GW-1)
18	7	3	1

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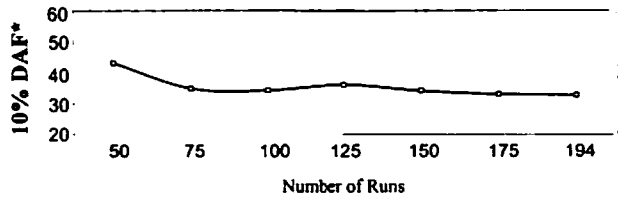
Leaching

40.0985

Range of Results using Mass-Specific Data

Even without modifying source area parameters, the range of Mass-specific values demonstrate variability expected in DAF given site-variability

o-Xylene



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Vapor Infiltration ("VI")

40.0986

- Modify Method 1 (or 2) standards based on site-specific information
  - Develop an alternative VI-based groundwater concentration
  - Demonstrate that VI is not a concern at the site
  - Use modeling of source, subsurface hydrogeological and building conditions
  - Use soil gas characterization, indoor air data or other field investigations
  - UCL is the upper limit to allowed Method 2 modification

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Vapor Infiltration

40.0986

- Use MassDEP or USEPA spreadsheets based on Johnson & Ettinger model
  - Use MassDEP default exposure parameters
  - Use MassDEP default chemical parameters (if available)
  - Use site-specific characteristics

MassDEP

Vapor Infiltration

40.0986

Sensitivity Analysis of Site-Specific Factors

Parameter	Change in Parameter	Change in GW-2 Standard
Depth to bottom of basement floor	⇩	⇧⇧
Depth to Water Table	⇧	⇧⇧⇧
Soil Dry Bulk Density	⇧	⇧
Soil Water-Filled Porosity	⇧	⇧⇧⇧
Soil Total Porosity	⇧	⇩⇩

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Vapor Infiltration

40.0986

- Resources:
  - USEPA Spreadsheets — Good for 1 contaminant
    http://epa.gov/superfund/programs/risk/airmodel/johnson_ettinger.htm
  - MassDEP Spreadsheets — Good for multiple contaminants
    - Part of documentation to new Method 1 Standards
    - Will be available at http://mass.gov/dep/bwsc/files/standard/standard.htm

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Groundwater Transport/Discharge

40.0987

- Modify Method 1 (or 2) standards based on site-specific information
  - Develop an alternative groundwater concentration based on discharge to surface water
  - Demonstrate that surface water discharge is not occurring at the site
  - Use modeling of source, subsurface hydrogeological, and surface water body conditions
  - Use long-term monitoring NSR in the receiving surface water body
  - UCL is the upper limit to allowed Method 2 modification

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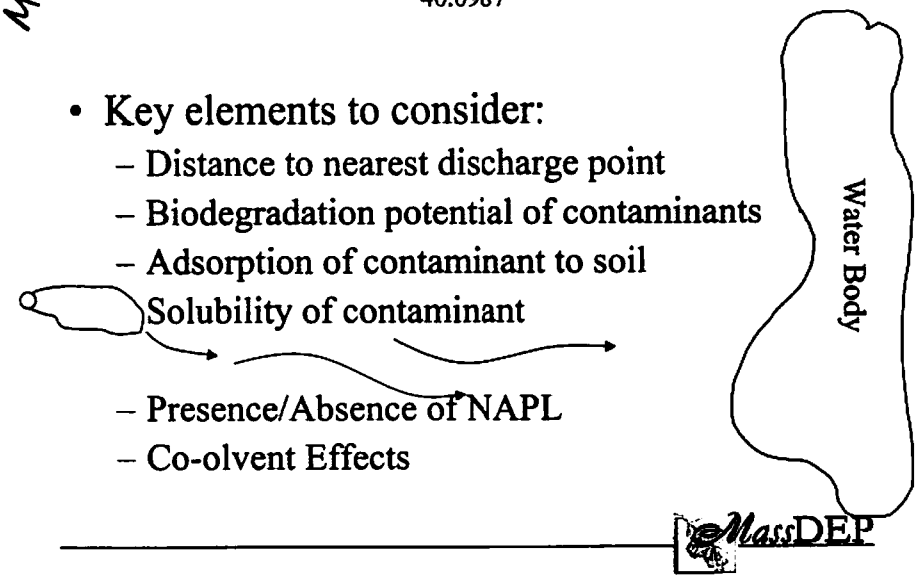
CAN CHANGE GW TOX FACTORS IN M2

Groundwater Transport/Discharge

40.0987

- Key elements to consider:
  - Distance to nearest discharge point
  - Biodegradation potential of contaminants
  - Adsorption of contaminant to soil
  - Solubility of contaminant
  - Presence/Absence of NAPL
  - Co-olvent Effects



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Method 2 Modifications Summary

- How much will it help without modifying risk/exposure parameters?
- Modifications capped by Ceiling Levels, UCLs, Direct Contact Standards.
- Likely to require specialized skills: risk assessment, hydrogeology, modeling
- Potential to use site data as documentation/justification for a "no impact" conclusion

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MCP Method 2 Risk Characterizations

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LSP Association/DEP Continuing Education Seminar Course #1294

Real World Examples

Example 1: Method 2 GW-1 Standard for 1,3,5-trimethylbenzene (standard not available)

Example 2: Method 2 GW-2 Standard for 1,1-dichloroethene (change in toxicity factor)

Example 3: Method 2 GW-3 Standard for butylbenzylphthalate (Method 1 not available)

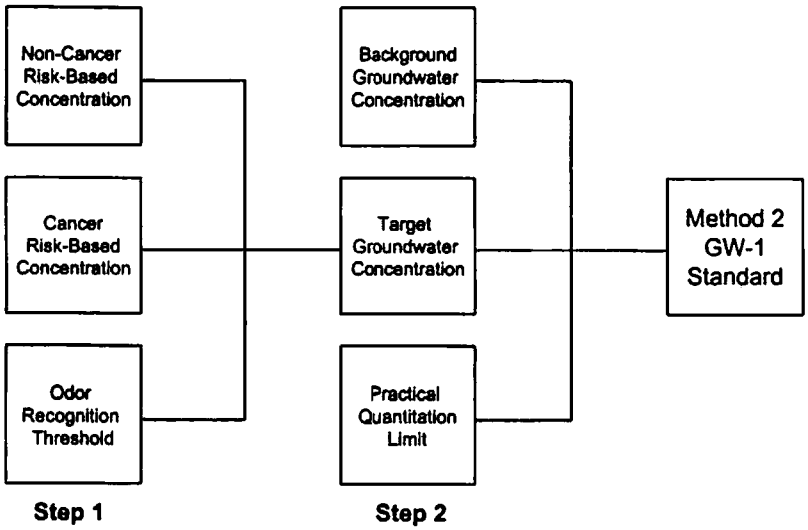
More Examples

Example 4: Method 2 GW-3 Standard for silver (site-specific evaluation of groundwater migration pathway)

Example 5: Method 2 Soil Standards for benzo(a)pyrene (changes prior to promulgation)

Example 6: Method 2 S-2/GW-2 Standard for naphthalene (site-specific evaluation of leaching potential)

Method 2 GW-1 Flow Chart



Example 1: Method 2 GW-1 Standard for 1,3,5-trimethylbenzene

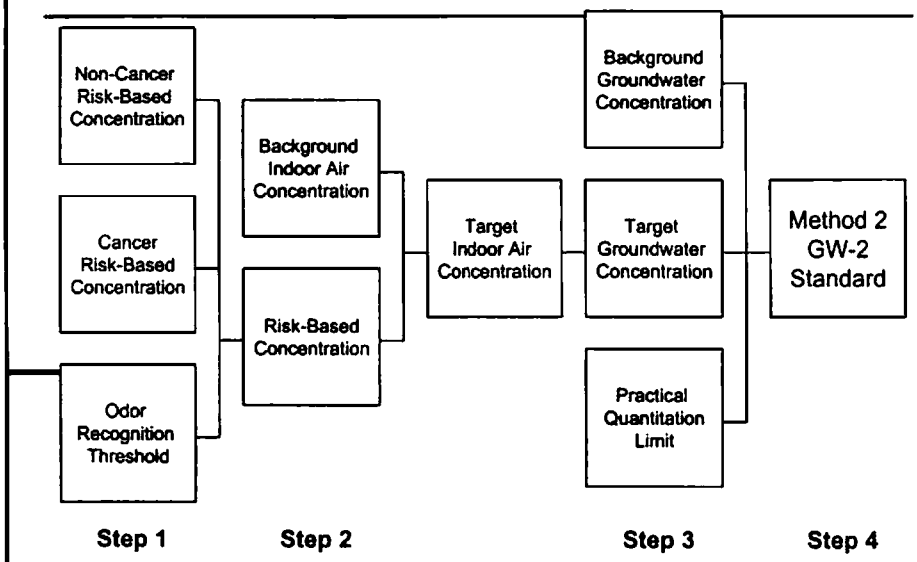
Highest of the following three values:

1. Target groundwater concentration from Step 1 = 350 ug/L (non-cancer risk based conc.)
2. Background Concentration = 0 ug/L
3. Practical quantitation limit = 2 ug/L

Ceiling concentration = 50,000 ug/L

Method 2 GW-1 Standard = 350 ug/L

Method 2 GW-2 Flow Chart



Example 2: Method 2 GW-2 Standard for 1,1-dichloroethene

1999 MCP Method 1 GW-2	2002 Method 2 GW-2	Wave 2 Method 1 GW-2
1 ug/L a = 5E-4	126 ug/L a = 5E-4	80 ug/L a = 7.87E-4

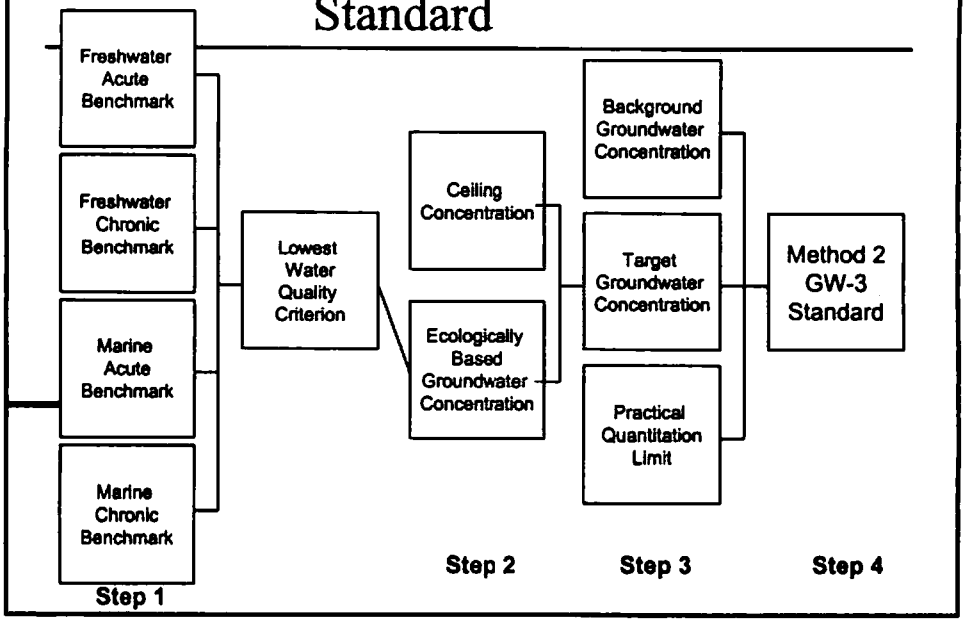
Change in toxicity factor: IRIS (2002) withdrew cancer slope factor and unit risk due to equivocal evidence of carcinogenicity (oral) and insufficient evidence of carcinogenicity (inhalation)

Non-cancer risk-based concentration now drives the standard

Change in attenuation factor reflected in proposed standard

Site-specific attenuation factor for vapor intrusion pathway could also be used

Step 4: Identify MCP Method 2 GW-3 Standard



Example 3: Method 2 GW-3 Standard for butylbenzylphthalate

Method 1 GW-3 Standard not available for this constituent

- Step 1: Identify ecologically-based water quality criteria = 19 ug/L
- Step 2: Calculate ecologically-based groundwater concentration = 4750 ug/L
- Step 3: Identify Target Groundwater Concentration = 4750 ug/L
- Step 4: Identify MCP Method 2 GW-3 Standard = 4750 ug/L

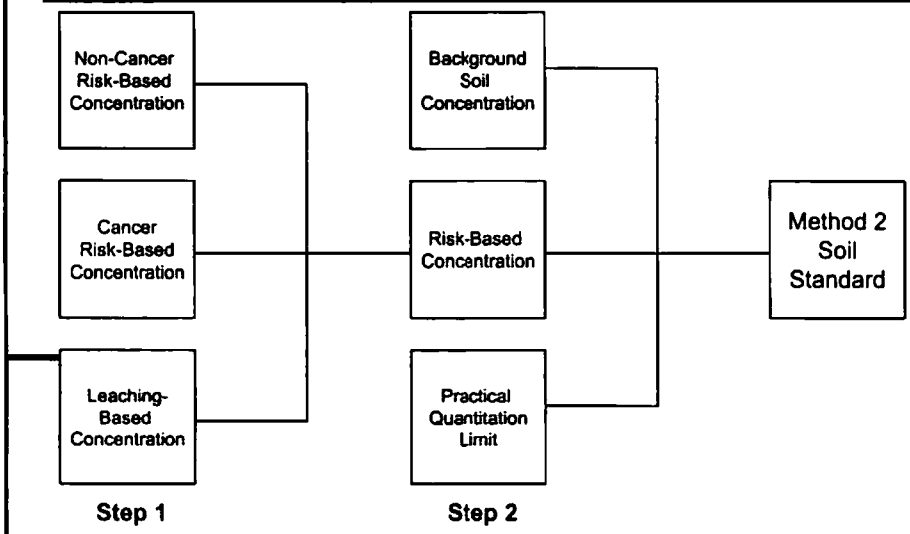
M2 ADJUSTMENTS CAUTION - MOST MILEAGE DILUTION ATTENUATION

Example 4: Method 1 and Method 2 GW-3 Standards for silver

	1999 MCP Method 1 GW-3	Site-specific Method 2 GW-3	Wave 2 Method 1 GW-3
GW-3 Standard	7 ug/L	120 ug/L	7 ug/L
Target [sw]	0.12 ug/L	0.12 ug/L	0.03 ug/L
Target [gw]	1.2 ug/L	120 ug/L	0.75 ug/L
DAF	10	1000	NA
DF x AF	NA	NA	10 x 2.5
PQL	7 ug/L	7 ug/L	7 ug/L

- Site-specific evaluation of groundwater migration pathway
- Default dilution attenuation factor DAF was 10
- Site-specific DAF ~1000
- Lowest Ecologically Based Criterion changed; EPA retracted LOAEL of 0.12 ug/L used as Target [sw]
- PQL becomes the standard

Soil Standard Derivation Flow Chart



Example 5: Method 2 Soil Standards for benzo(a)pyrene

	1999 MCP Method 1	2002 Method 2	Wave 2 Method 1
S-1 Standard	0.7 mg/kg	2 mg/kg	2 mg/kg
Background	0.5 mg/kg	2 mg/kg	2 mg/kg

- Technical Updates to the MADEP 1995 Guidance for Disposal Site Risk Characterization revise dermal contact rates for soil and provide background concentrations for PAHs and metals
- Taking advantage of updated guidance prior to promulgation of standards based on this guidance requires complete calculation and documentation of method

Wave 2 (2004) Soil Ingestion and Contact Rates

	S-1	S-2	S-3
	mg_{soil}/kg/day		
NADSIR	2.4	0.27	1.3
NADSCR	21	0.05	12.4
NLADSIR	0.38	0.11	0.01
NLADSCR	4.1	0.19	0.09

Example 6: Method 2 S-2/GW-2 Standard for naphthalene

	1999 MCP Method 1	Site-specific Method 2	Wave 2 Method 1
S-2/GW-2 Standard	1000 mg/kg	190 mg/kg	40 mg/kg
DAF	220	32	32
Basis	Leaching	Leaching - Using Wave 2 DAF identified by MADEP	Leaching - GW-2 Standard decreases under Wave 2

Use of new DAF methodology identified by MADEP but not yet promulgated.

Note: under Wave 2 DAFs vary by groundwater category,
e.g., naphthalene DAF = 32 (GW-1, -2) and 344 (GW-3)
Under Wave 2, MADEP has identified the 85th percentile DAF for use in calculating GW-1 and GW-2 soil standards and the 50th percentile DAF for use in GW-3 soil standards.

Leaching-Based Soil Standards

- Wave 2 Method 1 Standards that are based on leaching
  - S-1
    - GW-1: 49% (58), GW-2: 36% (43), GW-3: 13% (16)
  - S-2
    - GW-1: 53% (63), GW-2: 42% (50), GW-3: 18% (22)
  - S-3
    - GW-1: 55% (65), GW-2: 46% (55), GW-3: 21% (25)
- Wave 2 DAFs
  - 38 DAFs increase
    - Phenanthrene – current: 0.24 Wave 2: 248
    - Carbon tetrachloride – current: 207 Wave 2 : 2611
  - 28 DAFs decrease
    - Acetone – current: 45 Wave 2: 1
    - MtBE – current: 44 Wave 2: 2

Summary and Q&A

- Method 2 is the middle ground between generic Method 1 and fully site-specific Method 3 Risk Characterizations.
- Method 2 is appropriate if only limited modifications to standards are needed.
- Method 2 can be cost-effective depending on the number of standards derived and/or modified.
- Success using a Method 2 approach depends on site characteristics, exposure pathways and knowledge of allowable modifications.

DERIVATION OF MCP METHOD 2 GROUNDWATER (GW-1) STANDARD (ug/L)
1,3,5-Trimethylbenzene

Selected from the lowest of the following three values:	Value Used	Source of Value
1. Noncancer risk-based drinking water concentration [OHM]gw (ug/L) calculated using the following equation:(RfD (mg/kg-day) * 7000)/RAForal Where:	350	
RfD = Reference Dose published by U.S. EPA, mg/kg-day	0.05	RAIS, September 2001
7000 is calculated as (0.2*70 kg*1000 ug/mg)/(2 L/d) using the following:		
0.2, 20% source allocation factor	0.2	310 CMR 40.0983(2)a
70 kg, adult body weight	70	310 CMR 40.0983(2)a
1000 ug/mg, units conversion factor	1000	310 CMR 40.0983(2)a
2 L/day, drinking water ingestion rate	2	310 CMR 40.0983(2)a
RAF_{oral}, Relative Absorption Factor	1	assumed 100%
2. Cancer risk-based drinking water concentration [OHM]gw (ug/L) calculated using the following equation: 0.035/(CSF * RAF_{oral}) Where:	NA	
0.035 is calculated as (10^{-6}*70 kg*1000)/(2 L/d) using the following:		
10^{-6}, target risk level	0.000001	310 CMR 40.0983(2)b
70 kg, adult body weight	70	310 CMR 40.0983(2)b
1000 ug/mg, units conversion factor	1000	310 CMR 40.0983(2)b
2 L/day, drinking water ingestion rate	2	310 CMR 40.0983(2)b
CSF = Cancer Slope Factor for the chemical, published by U.S. EPA, $(mg/kg\text{-}day)^{-1}$	NA	IRIS, August 2001
RAF_{oral}, Relative Absorption Factor	1	assumed 100%
3. Odor Recognition Threshold ($ORL_{50\%}$) (ug/m^3):	NA	Ruth, 1986

RISK ASSESSMENT INFORMATION SERVICE (RAIS)

DERIVATION OF MCP METHOD 2 GROUNDWATER (GW-1) STANDARD (ug/L)
1,3,5-Trimethylbenzene

Selected from the highest of the following three values,	350	Source of Value
1. Target Groundwater Concentration, ug/L	350	Step 3.
2. Site-specific background concentration, ug/L	0	assumed
3. Practical Quantitation Limit (PQL), ug/L	2	U.S. EPA Method 8021
And adjusted to Ceiling Concentration, ug/L		
Ceiling Concentration (ug/l):	50,000	310 CMR 40.0983(5)

Abbreviations:

CMR = Code of Massachusetts Regulations, 310 CMR 40.0000 is the Massachusetts Contingency Plan

DEP = Massachusetts Department of Environmental Protection

gw = groundwater

IRIS = Integrated Risk Information System www.epa.gov/iris

NA = Not Applicable or Not Available.

OHM = Oil or Hazardous Material

$ORL_{50\%}$ = Odor Recognition Threshold at which 50% of population can detect odor of chemical

PQL = Practical Quantitation Limit

RAIS = Risk Assessment Information System http://risk.lsd.ornl.gov

RfC = Reference Concentration

UR = Unit Risk

U.S. EPA = United States Environmental Protection Agency

DERIVATION OF MCP METHOD 2 GROUNDWATER (GW-2) STANDARD (µg/L)
Chemical: 1,1-Dichloroethene

Selected from the lowest of the following three values:	Value Used	Source of Value
1. Noncancer risk-based indoor air concentration [OHM]air (ug/m^3) calculated using the following equation: 0.2 * Chronic RfC (ug/m^3)	40	
Where:		
0.2 = 20% source allocation factor	0.2	310 CMR 40.0983(2)a.1.
RfC = Reference Concentration published by U.S. EPA, ug/m^3.	200	IRIS, 2002.
2. Cancer risk-based indoor air concentration [OHM]air (ug/m^3) calculated using the following equation: $10^{-6} \div UR_{air}$ (ug/m^3)	NA	
Where:		
10^{-6} = A one-in-a-million Excess Lifetime Cancer Risk. Dimensionless.	0.000001	310 CMR 40.0983(2)a.2.
UR_{air} = Unit Risk in air for the chemical, published by U.S. EPA, ug/m^3.	NA	IRIS, 2002.
3. Odor Recognition Threshold ($ORL_{50\%}$) (ug/m^3):	125,000	ATSDR Toxicological Profile

Selected from the highest of the following two values:	
1. Background indoor air concentration for chemical	NA
2. Lowest value in Step 1.	40

DERIVATION OF MCP METHOD 2 GROUNDWATER (GW-2) STANDARD (µg/L)
Chemical: 1,1-Dichloroethene

STEP 3	Value Used	Source of Value
Calculated using the following equation:		
[OHM]gw = [OHM]air + (α * d * H * C)		
Where:		
[OHM]gw =The calculated groundwater concentration of the oil or hazardous material which would not result in an indoor air concentration greater than [OHM]air, ug/l.	126	
[OHM]air =The target indoor air concentration, ug/m^3.	40	Step 2.
α = Attenuation factor equal to 0.0005 (DEP default value). Dimensionless.	0.0005	310 CMR 40.0983(2)c
d = An applied dilution factor (DEP value). Dimensionless.	1	310 CMR 40.0983(2)c
H = Henry's Law Constant for the chemical. Dimensionless.	1	
C = Units Conversion Factor, 1000 liter/m3.	1000	310 CMR 40.0983(2)c

STEP 4		
Selected from the highest of the following three values,	126	Source of Value
1. Target Groundwater Concentration, ug/L	126	Step 3.
2. Site-specific background concentration, ug/L	0	assumed
3. Practical Quantitation Limit (PQL), ug/L	0.4 to 1	U.S. EPA Method 8021
And adjusted to Ceiling Concentration, ug/L		
Ceiling Concentration (ug/l):	50,000	310 CMR 40.0983(5)

Abbreviations:

CMR = Code of Massachusetts Regulations, 310 CMR 40.0000 is the Massachusetts Contingency Plan

DEP = Massachusetts Department of Environmental Protection

gw = groundwater

IRIS = Integrated Risk Information System www.epa.gov/iris

NA = Not Applicable or Not Available.

OHM = Oil or Hazardous Material

$ORL_{50\%}$ = Odor Recognition Threshold at which 50% of population can detect odor of chemical

PQL = Practical Quantitation Limit

RAIS = Risk Assessment Information System http://risk.lsd.ornl.gov

RfC = Reference Concentration

UR = Unit Risk

U.S. EPA = United States Environmental Protection Agency

DERIVATION OF MCP METHOD 2 GROUNDWATER (GW-3) STANDARD (µg/L)
Chemical: Butyl Benzyl Phthalate

Selected from the lowest of the following four values:	Value Used	Source of Value
1. Freshwater Acute Water Quality Criterion (µg/L):	NA	NAWC as listed in Suter and Tsao, 1996
2. Freshwater Chronic Water Quality Criterion (µg/L):	19	NAWC as listed in Suter and Tsao, 1996
3. Marine Acute Water Quality Criterion (µg/L):	NA	NAWC as listed in Suter and Tsao, 1996
4. Marine Chronic Water Quality Criterion (µg/L):	NA	NAWC as listed in Suter and Tsao, 1996

1. Calculated by multiplying the lowest value from Step 1 by DF and AF.	Value Used	Source of Value
Groundwater to Surface Water Dilution factor (DF)	10	310 CMR 40.0983(4)b.
Attenuation Factor (AF)	25	DEP Proposed based on Koc
Lowest value in Step 1.	19	
2. Ceiling Concentration (µg/L):	50,000	310 CMR 40.0983(5)

Selected from the lower of the following two values:	Value Used	Source of Value
1. Target Groundwater Concentration (µg/L):	4,750	
2. Background Concentration (µg/L):	NA	
3. Practical Quantitation Limit (µg/L):	2	

Abbreviations:

CMR = Code of Massachusetts Regulations, 310 CMR 40.0000 is the Massachusetts Contingency Plan (MCP)

DEP = Massachusetts Department of Environmental Protection

NA = Not Applicable or Not Available.

NAWC = National Ambient Water Criteria

Source:

U.S Environmental Protection Agency (USEPA). 2002. National Recommended Water Quality Criteria.

Is this a "good" standard?

Lowest Ecologically Based Criteria for Other Phthalates	
bis(2-ethylhexyl)phthalate	160 ug/L
diethylphthalate	340 ug/L

DERIVATION OF MCP METHOD 1 GROUNDWATER (GW-3) STANDARD (µg/L)
Chemical: Silver

Selected from the lowest of the following four values:	Value Used	Source of Value
1. Freshwater Acute Water Quality Criterion (µg/L):	0.3	NAWQC as listed in EPA, 1996
1. Freshwater Chronic Water Quality Criterion (µg/L):	0.03	CMC(FW)/10
3. Marine Acute Water Quality Criterion (µg/L):	NA	
4. Marine Chronic Water Quality Criterion (µg/L):	1.9	NAWQC as listed in EPA, 1996

1. Calculated by multiplying the lowest value from Step 1 by DF and AF.	Value Used	Source of Value
Groundwater to Surface Water Dilution factor (DF)	10	310 CMR 40.0983(4)b.
Attenuation Factor (AF)	2.5	DEP Proposed based on Koc
Lowest value in Step 1.	0.03	
2. Ceiling Concentration (µg/L):	50,000	310 CMR 40.0983(5)

Selected from the highest of the following values:	Value Used	Source of Value
1. Target Groundwater Concentration (µg/L):	0.75	
2. Background Concentration (µg/L):	4.7	DEP. 2004. Toxicity.xls
3. Practical Quantitation Limit (µg/L):	7	Wagner, Ed. 1992.

Abbreviations:

CMR = Code of Massachusetts Regulations, 310 CMR 40.0000 is the Massachusetts Contingency Plan (MCP)

DEP = Massachusetts Department of Environmental Protection

NA = Not Applicable or Not Available.

NAWQC = National Ambient Water Quality Criterion

Sources:

U.S Environmental Protection Agency (USEPA). 2002. *National Recommended Water Quality Criteria.*

USEPA. 1999. *National Recommended Water Quality Criteria-Correction*. EPA 822-Z-99-001

Guide to Environmental Analytical Methods, Robert E. Wagner, editor; Genium Publishing Corporation, Schenectady, NY; 1992.

MADEP "Surface water benchmark for derivation of GW-3 Standard is selected according to following sequence:

1. Select lowest NAWQC for environmental effects in saltwater or freshwater (CMC, CCC).
2. If above unavailable, select lowest chronic value from AQUIRE as ecological benchmark.
3. If all above unavailable, select lowest acute value from AQUIRE as ecological benchmark.
4. If all above unavailable, select lowest chronic value from ORNL (Suter and Tsao, 1996) or others as ecological benchmark.
5. If all above unavailable, select lowest chronic Tier II value from ORNL (Suter and Tsao, 1996) or others as ecological benchmark.
6. If only an acute value has been selected after steps 1-5, divide the acute value by 10 to estimate a chronic value as ecological benchmark.
7. Select surface water benchmark as the lower of the selected ecological benchmark or the NAWQC for fish consumption."

Notes:

Hardness dependent criteria, source document assumed 20 mg/L hardness, as CaCO3

DERIVATION OF MCP METHOD 2 S-1 SOIL STANDARD
Chemical: Benzo (a) pyrene

Selected from the lowest of the following three values:	Value Used	Source of Value
1. Noncancer risk-based soil concentration [OHM]soil (mg/kg) calculated using the following equation: $[OHM]soil = (RfD_{chronic} * 0.2 * C) + [(RAF_{oral} * 3.1) + (RAF_{dermal} * 28.5)]$	1,341	Calculated
Where:		
$RfD_{chronic}$ = Chronic Reference Dose published by U.S. EPA, mg/kg-day	0.04	IRIS, September 2002. Value for fluoranthene
0.2 = 20% source allocation factor	0.2	310 CMR 40.0984(2)
C = Units Conversion Factor, 10^6 mg/kg.	1000000	310 CMR 40.0984(2)
RAF_{oral} = Relative Absorption Factor for oral exposures. Dimensionless.	*0.91*	MADEP, 1994 Background Documentation
RAF_{dermal} = Relative Absorption Factor for dermal exposures. Dimensionless.	*0.18*	MADEP, 1994 Background Documentation
3.1 = Average daily exposure to soil by oral pathway	2.4	
28.5 = Average daily exposure to soil by dermal pathway	21	Proposed changes in exposure, MCP pre-public hearing draft, December 2001.
2. Cancer risk-based soil concentration [OHM]soil (mg/kg) calculated using the following equation: $[OHM]soil = (1 \times 10^{-6} * C) + [CSF * ((RAF_{oral} * 0.41) + (RAF_{dermal} * 7.3))]$	0.7	
Where:		
1×10^{-6} = A one-in-a-million Excess Lifetime Cancer Risk. Dimensionless.	0.000001	310 CMR 40.0984(3)
C = Units Conversion Factor, 10^6 mg/kg.	1000000	310 CMR 40.0984(3)
CSF = Cancer Slope Factor published by U.S. EPA, $(mg/kg\text{-}day)^{-1}$	7.3	IRIS, September 2002.
RAF_{oral} = Relative Absorption Factor for oral exposures. Dimensionless.	*0.28*	DEP, 2004. Toxicity.xls (proposed)
RAF_{dermal} = Relative Absorption Factor for dermal exposures. Dimensionless.	*0.02*	DEP, 2004. Toxicity.xls (proposed)
0.41 = Lifetime average daily exposure to soil by oral pathway	0.38	
7.3 = Lifetime average daily exposure to soil by dermal pathway	4.1	Proposed changes in exposure, MCP pre-public hearing draft, December 2001.
3. Leaching-based soil concentration [OHM]soil (mg/kg): calculated using the following equation: $[OHM]soil = DAF * [OHM]gw * C$	1	
Where:		
[OHM]soil = The leaching-based soil concentration (mg/kg)	1	
DAF = Dilution/Attenuation Factor calculated for the chemical. Dimensionless.	472	
[OHM]gw = Target groundwater concentration of the chemical (ug/l)	2	Method 1 GW-3 Standard
C = Conversion factor, 0.001 mg/ug	0.001	
The DAF is calculated using the following equation: $DAF = (6270 * H) + (0.166 * Koc)$		
H = Henry's Law Constant for the chemical ($atm\text{-}m^3/mol$)		U.S. EPA, Hazardous Waste Treatment, Storage and Disposal Facilities (TSDF)- Air Emission Models, December 1987.
	0.0146	
Koc = Organic carbon partition coefficient for the chemical (ml/g)	2290.86	RAIS, August 2000

DERIVATION OF MCP METHOD 2 S-1 SOIL STANDARD
Chemical: Benzo (a) pyrene

Selected from the highest of the following three values,	2	Source of Value
1. Risk-Based Soil Concentration, mg/kg	0.7	Step 1.
2. MADEP Identified Background Concentration in Soil, mg/kg	2	MADEP 2002
3. Practical Quantitation Limit (PQL), mg/kg	0.66	MADEP 1994
And adjusted to Ceiling Concentration, mg/kg		
Ceiling Concentration (mg/kg) calculated using the following equation:	1,000	310 CMR 40.0984(9)(a)3.
Odor Index = VP + $ORL_{50\%}$	NC	
Where:		
VP = Vapor pressure of chemical, units of Torr	5.00E-09	MADEP, 1994. Background Documentation for the Development of the MCP Numerical Standards. April.
$ORL_{50\%}$ = Odor Recognition Threshold at which 50% of population can detect odor of chemical, ppm	NA	

Abbreviations:
- CMR = Code of Massachusetts Regulations, 310 CMR 40.0000 is the Massachusetts Contingency Plan
- CSF = Cancer Slope Factor
- DAF = Dilution Attenuation Factor
- DEP = Massachusetts Department of Environmental Protection
- gw = groundwater
- IRIS = Integrated Risk Information System www.epa.gov/iris
- NA = Not Applicable or Not Available.
- OHM = Oil or Hazardous Material
- $ORL_{50\%}$ = Odor Recognition Threshold at which 50% of population can detect odor of chemical
- PQL = Practical Quantitation Limit
- RAIS = Risk Assessment Information System http://risk.lsd.ornl.gov
- RAF = Relative Absorption Factor
- RfD = Reference Dose
- U.S. EPA = United States Environmental Protection Agency
- VP = Vapor Pressure

DERIVATION OF MCP METHOD 2 S-2/GW-2 SOIL STANDARD
Chemical: Naphthalene

STEP

Selected from the lowest of the following three values:	Value Used	Source of Value
1. Noncancer risk-based soil concentration $[OHM]_{soil}$ (mg/kg) calculated using the following equation:	2,462	
$[OHM]soil = (RfD_{chronic} * 0.2 * C) \div [(RAF_{oral} * 0.29) + (RAF_{dermal} * 15.2)]$		
Where:		
$RfD_{chronic}$ = Chronic Reference Dose, mg/kg-day	0.02	(1)
0.2 = 20% source allocation factor	0.2	(2)
C = Units Conversion Factor, 10^6 mg/kg.	1000000	(2)
RAF_{oral} = Relative Absorption Factor for oral exposures. Dimensionless.	0.36	(3)
RAF_{dermal} = Relative Absorption Factor for dermal exposures. Dimensionless.	0.1	(3)
Average daily exposure to soil by oral pathway	0.29	(4)
Average daily exposure to soil by dermal pathway	15.2	(4)
2. Cancer risk-based soil concentration $[OHM]_{soil}$ (mg/kg) calculated using the following equation:	NA	
$[OHM]soil = (1 \times 10^{-6} * C) \div [CSF * ((RAF_{oral} * 0.11) + (RAF_{dermal} * 5.48)$		
Where:		
1×10^{-6} = A one-in-a-million Excess Lifetime Cancer Risk. Dimensionless.	1.0E-06	(5)
C = Units Conversion Factor, 10^6 mg/kg.	1.0E+06	(5)
CSF = Cancer Slope Factor published by U.S. EPA, $(mg/kg\text{-}day)^{-1}$	NA	
RAF_{oral} = Relative Absorption Factor for oral exposures. Dimensionless.	NA	
RAF_{dermal} = Relative Absorption Factor for dermal exposures. Dimensionless.	NA	
Lifetime average daily exposure to soil by oral pathway	0.11	(4)
Lifetime average daily exposure to soil by dermal pathway	5.48	(4)

DERIVATION OF MCP METHOD 2 S-2/GW-2 SOIL STANDARD
Chemical: Naphthalene

3. Leaching-based soil concentration $[OHM]_{soil}$ (mg/kg): calculated using the following equation:	192	
$[OHM]_{soil} = DAF * [OHM]_{gw} * C$		
Where:		
DAF = Dilution/Attenuation Factor calculated for the chemical. Dimensionless.	32	(6)
$[OHM]_{gw}$ = Target groundwater concentration of the chemical (ug/l)	6,000	(7)
C = Conversion factor, 0.001 mg/ug	0.001	

[redacted]

Selected from the highest of the following three values, rounded		Source of Value
1. Risk-Based Soil Concentration, mg/kg	192	Step 1.
2. MADEP Identified Background Concentration in Soil, mg/kg	0.5	(11)
3. Practical Quantitation Limit (PQL), mg/kg	0.66	(8)
And adjusted to Ceiling Concentration, mg/kg		
Ceiling Concentration (mg/kg) calculated using the following equation:	5,000	(10)
Odor Index = VP + $ORL_{50\%}$	0.98	
Where:		
VP = Vapor pressure of chemical, units of Torr	0.082	(8)
$ORL_{50\%}$ = Odor Recognition Threshold at which 50% of population can detect odor of chemical, ppm	0.084	(8)

DERIVATION OF MCP METHOD 2 S-2/GW-2 SOIL STANDARD
Chemical: Naphthalene

Abbreviations:

NA = Not Applicable or Not Available. NC = Not Calculated. OHM = Oil or Hazardous Material

Sources:

(1) United States Environmental Protection Agency (USEPA) Integrated Risk Information System (IRIS), May 2003. http://www.epa.gov/IRIS
(2) 310 CMR 40.0984(2) of the Massachusetts Contingency Plan
(3) Massachusetts Department of Environmental Protection (MADEP), 2001. "MCP Toxicity.xls"
(4) 310 CMR 40.0984(2)c (noncancer) and 310 CMR 40.0984(3)c (cancer)
(5) 310 CMR 40.0984(3) of the Massachusetts Contingency Plan
(6) 85th Percentile DAF from MADEP Probablistic Study.
(7) MCP GW-3 standard (310 CMR 40.0974(2))
(8) MADEP, 1994. Background Documentation for the Development of the MCP Numerical Standards. April.
(9) 310 CMR 40.0984(9)(c)2 of the Massachusetts Contingency Plan
(10) 310 CMR 40.0984(9)(c)3 of the Massachusetts Contingency Plan.
(11) MADEP, 2002. "Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soil," Technical Update to Section 2.3, Guidance for Disposal Site Risk Characterization - In Support of the Massachusetts Contingency Plan (1995). May.

Beyond Method 2…
Revised ShortForms
In Support of MCP Method 3 Risk Assessments

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MassDEP

Goals for Revised ShortForm
(continued)

- Provide ShortForms for additional scenarios
  - construction worker
  - landscape worker
  - recreational child
  - trespasser

MassDEP

Intended Use of Revised ShortForm

- Risk calculation portion of Method 3 risk assessment
- Designed to be used by risk assessors to conduct risk assessments
- Provide documentation tables for a Method 3 risk assessment report

MassDEP

General Description

Set of Excel workbooks

- VLookup workbook (v0705) - database
- Exposure scenario workbooks (e.g., sf05dw, sf05rs)

MassDEP

General Description

(continued)

VLookup workbook

- Database that contains chemical-specific information
- Provides data to Exposure Scenario Workbooks using 'name recognition'
- Not printable

MassDEP

General Description
(continued)

Exposure scenario workbooks

- Scenario workbooks calculate risks
- Scenario workbooks are receptor- and medium-specific
- Scenario worksheets provide print-ready tables with complete documentation

MassDEP

General Description
(continued)

Scenario workbooks contain most relevant exposure pathways

For example:

- Residential Soil (rs) covers
  - ingestion, dermal contact, produce consumption
- Residential Drinking Water (dw) covers
  - ingestion, showering

MassDEP

Living Document

- VLookup and individual ShortForms on web
- Always check for latest version
- Version number listed in tables

MassDEP

Limitations

- ShortForms do not cover all exposure pathways
- Exposure assumptions are not site-specific
- Validity of results dependent upon good EPCs
- ShortForms do not write the report

MassDEP

Limitations

Only part of the Risk Assessment

- Hazard Identification
- Dose-Response Assessment
- Exposure Assessment
- Risk Characterization

MassDEP

Limitations
(continued)

Still need a risk assessor!

MassDEP

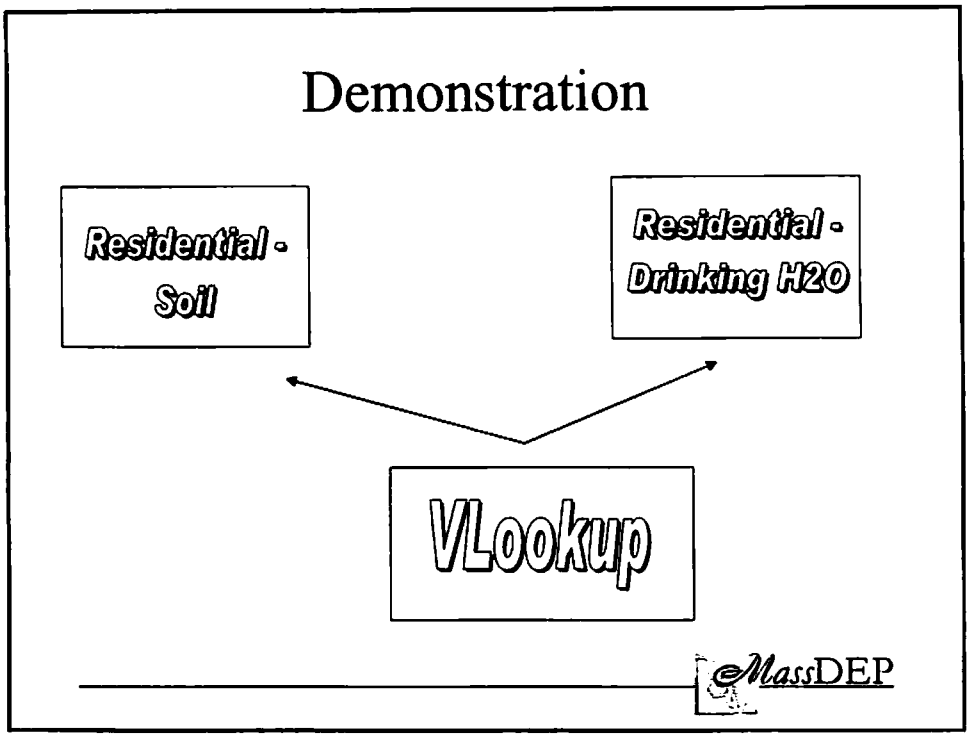
Differences from Old ShortForm

- Comparison to background not included
- Variety of receptors provided
- Chemical-specific values updateable by ORS

Differences from Old ShortForm (continued)

- Uses dermal uptake and inhalation model for shower exposure
- Ready-to-print documentation provided

Demonstration



Method 3 Risk Assessment for Chemicals in Drinking Water Shortform 2005 (sf05dw)

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Drinking Water: Table DW-1
Exposure Point Concentration (EPC) and Risk
Based on Resident Ages 1-31 (Cancer) and 1-6 (Noncancer)

Vlookup Version v0705

ELCR (all chemicals) = 1.E-05
HI (all chemicals) = 1

****Do not insert or delete any rows****

Click on empty cell below and select OHM using arrow.

Oil or Hazardous Material (OHM)	EPC (µg/L)	ELCR ingestion	ELCR dermal	ELCR inhalation	$ELCR_{total}$	Chronic HQ_{ing}	Chronic HQ_{derm}	Chronic HQ_{inh}	HQ_{total}
Benzene	5.0E-01	5.1E-07	7.6E-08	1.3E-06	1.9E-06	7.4E-03	1.2E-03	1.5E-02	2.3E-02
Benzo(a)pyrene	2.0E-02	2.7E-06	3.0E-06	4.9E-08	5.7E-06	3.6E-05	4.3E-05	1.3E-06	8.0E-05
Dichloroethylene, 1,1-	2.0E+01					2.4E-02	3.0E-03	8.5E-02	1.1E-01
Ethylbenzene	3.0E+00					1.8E-03	1.0E-03	2.4E-03	5.2E-03
Fluoranthene	3.0E+00					4.4E-03	9.6E-04	2.8E-03	8.2E-03
Hmx	2.0E+00					2.4E-03	1.5E-05	7.7E-14	2.4E-03
Indeno(1,2,3-cd)pyrene	5.0E-02	6.8E-07	7.4E-07	1.7E-08	1.4E-06	8.9E-05	1.1E-04	4.3E-06	2.0E-04
Naphthalene	5.0E+00					1.5E-02	1.0E-02	9.2E-01	9.4E-01
C11 to C22	2.0E+00					3.6E-03			3.6E-03
Rdx	1.0E+00	2.1E-06	1.6E-08	4.0E-07	2.5E-06	2.0E-02	1.6E-04	3.2E-03	2.3E-02
Toluene	2.0E+00					5.9E-04	1.9E-04	4.2E-03	5.0E-03
Trichloroethane, 1,1,2-	1.0E-01	1.1E-07	9.1E-09	3.7E-07	4.9E-07	1.5E-03	1.3E-04	8.5E-04	2.4E-03
Trichloroethylene	2.0E+00	4.1E-07	6.3E-08	9.5E-07	1.4E-06	5.9E-02	9.3E-03	8.3E-03	7.7E-02
Vinyl chloride	1.0E-02	4.0E-07	2.0E-08	3.2E-08	4.5E-07	2.0E-04	1.0E-05	9.9E-05	3.1E-04
Xylenes (mixed isomers)	1.0E+01					2.9E-03	1.8E-03	1.3E-01	1.4E-01

WASH YOUR UNITS!

EXCESS LIFETIME CANCER RISK (ELCR)

Drinking Water: Table DW-2
Equations to Calculate Cancer Risk for Resident (Age 1-31 years)

Vlookup Version v0705

Cancer Risk from Ingestion

$$ELCR_{ing} = LADD_{ing(1\text{-}31)} * CSF$$

$$LADD_{ing(1\text{-}31)} = LADD_{ing(1\text{-}8)} + LADD_{ing(8\text{-}15)} + LADD_{ing(15\text{-}31)}$$

$$LADD_{ing(age\ group\ x)} = \frac{EPC * VI_x * RAF_{c\text{-}ing} * EF * ED_{ing} * EP_x * C}{BW_x * AP_{lifetime}}$$

Cancer Risk from Dermal Absorption

$$ELCR_{derm} = LADD_{derm(1\text{-}31)} * CSF$$

$$LADD_{derm(1\text{-}31)} = LADD_{derm(1\text{-}8)} + LADD_{derm(8\text{-}15)} + LADD_{derm(15\text{-}31)}$$

$$LADD_{derm(age\ group\ x)} = \frac{DA_x * SA_x * EF * ED_{derm} * EP_x}{OAE_c * BW_x * AP_{lifetime}}$$

or, if outside "Effective Predictive Domain", then

$$LADD_{derm(age\ group\ x)} = \frac{EPC * VI_x * EF * ED_{derm} * EP_x * DM * C}{OAE_c * BW_x * AP_{lifetime}}$$

Cancer Risk from Inhalation

$$ELCR_{inh} = LADE_{(1\text{-}31)} * URF$$

$$LADE_{(1\text{-}31)} = LADE_{(1\text{-}8)} + LADE_{(8\text{-}15)} + LADE_{(15\text{-}31)}$$

$$LADE_{(age\ x)} = \frac{IEC_{S\text{-}x} * EF * ED_{inh\text{-}x} * EP_x}{AP_{lifetime}}$$

Parameter	Value	Units
CSF	OHM-specific	$(mg/kg\text{-}day)^{-1}$
URF	OHM-specific	$(\mu g/m^3)^{-1}$
LADD	age/OHM-specific	mg/kg-day
LADE	age/OHM-specific	$\mu g/m^3$
EPC	OHM-specific	µg/L
$VI_{(1\text{-}8)}$	1	L/day
$VI_{(8\text{-}15)}$	2	L/day
$VI_{(15\text{-}31)}$	2	L/day
$RAF_{c\text{-}ing}$	OHM-specific	dimensionless
EF	1	event/day
$ED_{ing\ \&\ derm}$	1	day/event
$ED_{inh(1\text{-}8)}$	0.046	day/event
$ED_{inh(8\text{-}15)}$	0.046	day/event
$ED_{inh(15\text{-}31)}$	0.044	day/event
$EP_{(1\text{-}8)}$	7	years
$EP_{(8\text{-}15)}$	7	years
$EP_{(15\text{-}31)}$	16	years
C	0.001	mg/µg
$BW_{(1\text{-}8)}$	17	kg
$BW_{(8\text{-}15)}$	39.9	kg
$BW_{(15\text{-}31)}$	58.7	kg
$AP_{(lifetime)}$	70	years
$IEC_{S\text{-}x}$	age/OHM-specific	$\mu g/m^3$
DA_x	age/OHM-specific	mg/cm^2
OAE_c	OHM-specific	dimensionless
$SA_{(1\text{-}8)}$	7130	cm^2
$SA_{(8\text{-}15)}$	12800	cm^2
$SA_{(15\text{-}31)}$	16731	cm^2
DM	OHM-specific	dimensionless

Drinking Water: Table DW-3
Equations to Calculate Noncancer Risk for Resident Child (Age 1-8 years)

Vlookup Version v0705

Noncancer Risk from Ingestion

$$HQ_{ing} = \frac{ADD_{ing}}{RfD}$$

$$ADD_{ing} = \frac{EPC * VI * RAF_{nc\text{-}ing} * EF * ED_{ing} * EP * C}{BW * AP}$$

Noncancer Risk from Dermal Absorption

$$HQ_{derm} = \frac{ADD_{derm}}{RfD}$$

$$ADD_{derm} = \frac{DA * SA * EF * ED_{derm} * EP}{OAE_{nc} * BW * AP}$$

or, if DA is outside the "Effective Predictive Domain" of the dermal model, then

$$ADD_{derm} = \frac{EPC * VI * EF * ED_{derm} * EP * DM * C}{OAE_{nc} * BW * AP}$$

Noncancer Risk from Inhalation

$$HQ_{inh} = \frac{ADE}{RfC}$$

$$ADE = \frac{IEC_S * EF * ED_{inh} * EP * C}{AP}$$

Parameter	Value	Units
RfD	OHM-specific	mg/kg-day
RfC	OHM-specific	mg/m^3
ADD_{ing}	OHM-specific	mg/kg-day
ADD_{derm}	OHM-specific	mg/kg-day
ADE	OHM-specific	mg/m_3
EPC	OHM-specific	µg/L
VI	1	L/day
$RAF_{nc\text{-}ing}$	OHM-specific	dimensionless
$RAF_{nc\text{-}derm}$	OHM-specific	dimensionless
EF	1	event/day
ED_{ing}	1	day/event
ED_{derm}	1	day/event
ED_{inh}	0.046	day/event
EP	7	years
C	0.001	mg/µg
BW	17	kg
$AP_{(noncancer)}$	7	years
IEC_S	OHM-specific	$µg/m^3$
DA	OHM-specific	mg/cm^2-shower
OAE_{nc}	OHM-specific	dimensionless
SA	7130	cm^2
DM	OHM-specific	dimensionless

Drinking Water: Table DW-4
Equations to Calculate Absorbed Dermal Dose from Showering (DA)

Vlookup Version v0705

Model equations obtained from U.S. EPA (2001) Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim (http://www.epa.gov/superfund/programs/risk/ragse/).

Steady State versus Non-Steady State for Organic Chemicals: The time for an organic chemical to reach steady state is a function of the chemical's molecular weight (MW) and it's ability to traverse skin (expressed as a permeability constant, Kp). If an organic chemical does not reach steady state before the shower is over (i.e., time to reach steady state, t^*, is greater than the shower duration, D_t), Equation (1) is used to calculate the dermal dose for this non-steady state. For organic chemicals that have reached a steady state by the end of the shower, Equation (2) is used to calculate dermal dose.

Effective Predictive Domain: The model is not used for organic chemicals that fall outside its effective predictive domain. Strictly, chemicals with very large or very small Kow values are outside of the EPD. Chemicals outside the Effective Predictive Domain are identified with an asterix in Tables B-2 and B-3 in the above citation as well as in Table V2 in the Vlookup (V) workbook.
For these chemicals, the dermal dose is estimated as a function of the oral dose according to MA DEP (1995) Guidance for Disposal Site Risk Characterization and Equation (3) below. Note that the dermal dose in these cases are calculated as an average daily dose (ADD) or life-time average daily dose (LADD) and expressed in mg/kg-bw. Equation (3) is also presented in Tables DW-2 and DW-3.

(1) Organic Chemicals Inside Effective Predictive Domain - *Non-Steady State*

Equation for estimating dermally absorbed dose (DA) for organic chemicals when the shower duration (D_t) is less than or equal to the time to reach steady state (t^*).

$$DA = 2 * FA * C * Kp * Cw * \sqrt{\frac{6 * \tau * D_s}{\pi}}$$

(2) Organic Chemicals Inside Effective Predictive Domain - *Steady State*

Equation for estimating DA for organic chemicals when D_t is greater than the time to reach t^*.

$$DA = FA * C * Kp * Cw * \left[\left(\frac{D_s}{1+B}\right) + 2 * \tau * \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]$$

(3) Organic Chemicals Outside Effective Predictive Domain

$$(L)ADD = \frac{EPC * VI * EF * ED_{dom} * EP * DM * C}{OAE * BW * AP}$$

(4) Inorganic Chemicals

Equation for estimating DA for inorganic chemicals in water.

$$DA = C * Kp * Cw * D_s$$

Where the equations to calculate the input values are:

(a) Equation for predicting strateum corneum permeability constant (Kp) for organic chemicals:

$$Kp = 10^{\left(-2.8 + 0.67 * \log Kow - 0.0056 * MW\right)}$$

(b) Equation for calculating ratio of permeability of chemical in strateum corneum to permeability in viable epidermis (B)

$$B = Kp * \frac{\sqrt{MW}}{2.6}$$

(c) Calculations for calculating time to reach steady state (t^*):

When B is less than or equal to 0.6

$$t^* = 2.4 * \tau$$

When B is greater than 0.6

$$t^* = \left(b - \sqrt{b^2 - c^2}\right) * \frac{l_{sc}^2}{D_{sc}}$$

Drinking Water: Table DW-4
Equations to Calculate Absorbed Dermal Dose from Showering (DA)

Vlookup Version v0705

(d) Equations for calculating b and c

$$c = \frac{1 + 3B + 3B^2}{3 * (1 + B)} \qquad b = \frac{2(1 + B)^2}{\pi} - c$$

(e) Equation for calculating lag time (τ)

$$\tau = \frac{l_{sc}^2}{6 * D_{sc}}$$

(f) Equation for calculating effective diffusivity (D_{sc})

$$D_{sc} = 10^{-2.8-(0.0056 * MW)} * l_{sc}$$

Parameter	Value	Units	Notes
DA_{event} - Absorbed dose per event per area skin exposed	calculated	mg/cm^2-event	see Table DW-4 and DW-5
FA - Fraction absorbed	OHM-specific	dimensionless	see Table DW-5
Kp - Strateum corneum (sc) permeability constant	OHM-specific	cm/hr	see Table DW-9
C - Conversion Factor	0.000001	m^3/cm^3	
C_w - [OHM] in water	OHM-specific	mg/m^3	see Table DW-1
τ - Lag time	calculated	hrs	Time for chemical to cross strateum corneum (Table DW-5)
D_t - Shower Duration	age-specific	hrs	see Table DW-6
$LogK_{ow}$ - Octanol/water partition coefficient	OHM-specific	dimensionless	see Table DW-9
MW - Molecular Weight	OHM-specific	g/mole	see Table DW-9
t* - Time to reach steady state	calculated	hr	see Table DW-5
b - Empirical variable used to calculate t*	calculated	dimensionless	see Table DW-5
c - Empirical variable used to calculate t*	calculated	dimensionless	see Table DW-5
l_{sc} - Thickness of skin	0.001	cm	MA DEP (1995). Guidance for Disposal Site Risk Characterization. Appendix Table B-9.
D_{sc} - Effective diffusivity for chemical transfer through the skin	calculated	cm^2/hr	see Table DW-5
B - Ratio of permeability of chemical in strateum corneum to permeability of chemical in viable epidermis	calculated	dimensionless	see Table DW-5

Drinking Water: Table DW-5
Dermal Absorded Dose (DA) from Showering

Vlookup Version v0705

Oil or Hazardous Material	Ratio of perm. in stratum corneum to viable epidermis B	Lag Time (tau) hours	Effective Diffusivity of Chemical Transfer Through Skin Dsc	Time to Reach Steady State t* hours	t* when B>0.6	b	c	Absorbed Dose (1-8) DA (mg/cm^2)	Absorbed Dose (8-16) DA (mg/cm^2)	Absorbed Dose (16-31) DA (mg/cm^2)	Outside Effective Predictive Domain	Fraction Absorbed FA	Absorbed Dose (1-8) w/ FA term $DA_{(1-8)}$ (mg/cm^2)	Absorbed Dose (8-16) w/ FA term $DA_{(8-16)}$ (mg/cm^2)	Absorbed Dose (16-31) w/ FA term $DA_{(16-31)}$ (mg/cm^2)	Dermal Mult. DM
Benzene	5.26E-02	0.288	5.80E-07	0.69		3.4E-01	3.7E-01	1.2E-08	1.1E-08	8.5E-09		1	1.15E-08	1.10E-08	8.49E-09	
Benzo(a)pyrene	4.59E+00	2.710	6.15E-08	11.81	11.81	1.5E+01	4.6E+00	6.0E-08	5.7E-08	5.1E-08	*	1	5.97E-08	5.73E-08	5.06E-08	1
Dichloroethylene, 1,1-	4.60E-02	0.367	4.54E-07	0.88		3.3E-01	3.6E-01	3.5E-07	3.4E-07	3.0E-07		1	3.55E-07	3.41E-07	3.01E-07	
Ethylbenzene	2.06E-01	0.413	4.04E-07	0.99		4.4E-01	4.8E-01	2.4E-07	2.3E-07	2.1E-07		1	2.42E-07	2.33E-07	2.05E-07	
Fluoranthene	1.33E+00	1.422	1.17E-07	5.59	5.59	2.0E+00	1.5E+00	2.1E-06	2.0E-06	1.8E-06	*	1	2.10E-06	2.01E-06	1.78E-06	0.2
Hmx	3.44E-04	4.793	3.48E-08	11.50		3.0E-01	3.3E-01	5.5E-10	5.3E-10	4.6E-10		1	5.49E-10	5.27E-10	4.65E-10	
Indeno(1,2,3-cd)pyrene	7.39E+00	3.694	4.51E-08	16.53	16.53	3.7E+01	7.4E+00	2.7E-07	2.6E-07	2.3E-07	*	0.6	1.61E-07	1.54E-07	1.36E-07	1
Naphthalene	2.15E-01	0.548	3.04E-07	1.31		4.5E-01	4.9E-01	4.4E-07	4.2E-07	3.7E-07		1	4.42E-07	4.24E-07	3.74E-07	
C11 to C22		0.728	2.29E-07			3.0E-01	3.3E-01									
Rdx	1.98E-03	1.847	9.02E-08	4.43		3.0E-01	3.3E-01	1.1E-09	1.1E-09	9.6E-10		1	1.13E-09	1.09E-09	9.59E-10	
Toluene	1.20E-01	0.344	4.84E-07	0.83		3.8E-01	4.2E-01	9.2E-08	8.9E-08	7.8E-08		1	9.25E-08	8.88E-08	7.83E-08	
Trichloroethane, 1,1,2-	2.99E-02	0.584	2.85E-07	1.40		3.2E-01	3.5E-01	1.2E-09	1.2E-09	1.1E-09		1	1.24E-09	1.19E-09	1.05E-09	
Trichloroethylene	5.39E-02	0.569	2.93E-07	1.37		3.4E-01	3.7E-01	4.5E-08	4.3E-08	3.8E-08		1	4.46E-08	4.28E-08	3.78E-08	
Vinyl chloride	1.75E-02	0.237	7.03E-07	0.57		3.1E-01	3.5E-01	7.3E-11	7.0E-11	5.7E-11		1	7.33E-11	6.99E-11	5.70E-11	
Xylenes (mixed isomers)	2.23E-01	0.413	4.04E-07	0.99		4.6E-01	5.0E-01	8.7E-07	8.4E-07	7.4E-07		1	8.72E-07	8.37E-07	7.39E-07	

Drinking Water: Table DW-6
Equations to Calculate Inhalation Exposure Concentration in the Shower (IEC_S)

Vlookup Version v0705

Model equations obtained from Foster, S.A. and Chrostowski, P.C. (1987) Inhalation Exposures to Volatile Organic Contaminants in the Shower. Presentation at the 80th Annual Meeting of APCA. New York, NY. June 21-26, 1987.

(1) Inhalation Exposure Concentration in the Shower.

$$IEC_S = \left(\frac{S}{R_{ae}} \times \left(D_s + \frac{e^{-R_{ae} D_t}}{R_{ae}} - \frac{e^{R_{ae}(D_s - D_t)}}{R_{ae}} \right) \times n \right) \div D_t$$

Where the equations to calculate the input values are:

(a) Indoor Air Generation Rate

$$S = \frac{C_{wd} \times FR}{SV}$$

(b) Concentration Leaving Water Droplet

$$C_{wd} = C_{w0}(1 - e^{\frac{-K_{aL} \times t_r}{60d}})$$

(c) Adjusted Mass Transfer Coefficient

$$K_{aL} = K_L \times \sqrt{\frac{T_l \times \mu_s}{T_s \times \mu_l}}$$

(d) Overall Mass Transfer Coefficient

$$K_L = \left(\frac{1}{k_l} + \frac{R \times T}{HLC \times k_g} \right)^{-1}$$

(e) Liquid Film Mass Transfer Coefficient

$$K_L = \left(\frac{1}{k_l} + \frac{R \times T}{HLC \times k_g} \right)^{-1}$$

(f) Gas Film Mass Transfer Coefficient

$$k_g = k_g(H_2O) \times \sqrt{\frac{MW_{H2O}}{MW_{VOC}}}$$

Drinking Water: Table DW-6
Equations to Calculate Inhalation Exposure Concentration in the Shower (IEC_S)

Vlookup Version v0705

Parameter	Value	Units	Notes
IEC_S - Inhalation Exposure Concentration in shower	calculated	$\mu g/m^3$	see Table DW-7
S - Indoor air generation rate	calculated	$\mu g/m^3$-min	see Table DW-7
R_{ac} - Air Exchange Rate	8.33E-03	1/min	MADEP. 1995. Guidance for Disposal Site Risk Characterization. Appendix Table B-9.
D_s - Shower Duration for age group 1-8	45.7	min	see Table DW-8
	0.76	hour	see Table DW-8
D_t - Total Time in Shower Room for age group 1-8	65.7	min	see Table DW-8
D_s - Shower Duration for age group 8-15	42.1	min	see Table DW-8
	0.70	hr	see Table DW-8
D_t - Total Time in Shower Room for age group 8-15	66.4	min	see Table DW-8
D_s - Shower Duration for age group 15-31	32.8	min	see Table DW-8
	0.55	hr	see Table DW-8
D_t - Total Time in Shower Room for age group 15-31	62.8	min	see Table DW-8
C_{wd} - Concentration leaving water droplet	calculated	µg/l	see Table DW-7
FR - Shower Flow Rate	10	1/min	MADEP. 1995. Guidance for Disposal Site Risk Characterization. Appendix Table B-9.
SV - Shower room air volume	6	m^3	Ibid
C_{w0} - Shower water concentration	OHM-specific	µg/l	EPC. See Table DW-1
K_{aL} - Adjusted mass transfer coefficient	calculated	cm/hr	see Table DW-7
t_s - Shower droplet time	2	seconds	MADEP. 1995. Guidance for Disposal Site Risk Characterization. Appendix Table B-9.
d - Droplet diameter	1	mm	Ibid
60d = Droplet interfacial area	60	cm/hr-seconds	the specific interfacial area, 6/d, for a spherical droplet of diamter d (mm), multiplied by conversion factors, hr/3600 seconds and 100 mm/cm
K_L - Overall mass transfer coefficient	calculated	cm/hr	see Table DW-7
Tl = Calibration water temperature of K_L	293	°K	MADEP. 1995. Guidance for Disposal Site Risk Characterizaiton. Appendix Table B-9.
µs - Water viscosity at Ts	0.596	cp	Ibid
T_s - Shower water temperature	318	°K	Ibid
μ_l - Water viscosity at T_l	1.002	cp	Ibid
k_l - Liquid film mass transfer coefficient	calculated	cm/hr	see Table DW-7
R - Universal Gas Constant	8.2E-05	atm-m^3/mol-°K	MADEP. 1995. Guidance for Disposal Site Risk Characterizaiton. Appendix Table B-9.
T - Absolute temperature	293	°K	Ibid
HLC - Henry's Law Constant	OHM-specific	atm-m^3/mol	see Table DW-7
k_g - Gas-film mass transfer coefficient	calculated	cm/hr	see Table DW-7
$k_l(CO_2)$ - Liquid-film mass transfer coefficient, CO_2	20	cm/hr	MADEP. 1995. Guidance for Disposal Site Risk Characterizaiton. Appendix Table B-9.
MW_{CO2} - Molecular weight of CO_2	44	g/mole	Ibid
MW_{VOC} - Molecular Weight of OHM	OHM-specific	g/mole	Ibid
$k_g(H_2O)$ - Gas-film mass transfer coefficient, water	3000	cm/hr	Ibid
MW_{H2O} - Molecular weight of water	18	g/mole	Ibid

Drinking Water: Table DW-7
Inhalation Exposure Concentration in the Shower (IEC_S)

Vlookup Version v0705

Oil or Hazardous Material	Henry's Law Constant HLC atm-m3/mol	Molecular Weight MW g/mole	INTERIM CALCULATIONS: gas-film mass transfer coefficient k_g (cm/hr)	liquid-film mass transfer coefficient k_l (cm/hr)	Overall Mass Transfer Coefficient K_L (cm/hr)	Adjusted Mass Transfer Coefficient K_{al} (cm/hr)	Concentration Leaving Water Droplet C_{wd} (µg/l)	Indoor Air Generation Rate S (µg/(m3-min))	Inhalation Exposure Concentration $IEC_{S(1-4)}$ (µg/m³)	Inhalation Exposure Concentration $IEC_{S(0-15)}$ (µg/m³)	Inhalation Exposure Concentration $IEC_{S(15-31)}$ (µg/m³)
Benzene	5.55E-03	78	1441.15	15.02	14.37	19.41	2.4E-01	4.0E-01	9.8E+00	9.4E+00	7.9E+00
Benzo(a)pyrene	1.13E-06	252	801.78	8.36	0.04	0.05	3.4E-05	5.6E-05	1.4E-03	1.3E-03	1.1E-03
Dichloroethylene, 1,1-	2.61E-02	97	1292.32	13.47	13.34	18.02	9.0E+00	1.5E+01	3.7E+02	3.6E+02	3.0E+02
Ethylbenzene	7.88E-03	106	1236.25	12.89	12.49	16.87	1.3E+00	2.2E+00	5.3E+01	5.1E+01	4.3E+01
Fluoranthene	1.61E-05	202	895.53	9.33	0.56	0.76	7.5E-02	1.3E-01	3.1E+00	3.0E+00	2.5E+00
Hmx	2.60E-15	296.2	739.55	7.71	0.00	0.00	7.2E-12	1.2E-11	3.0E-10	2.8E-10	2.4E-10
Indeno(1,2,3-cd)pyrene	1.60E-06	276	766.13	7.99	0.05	0.07	1.1E-04	1.9E-04	4.7E-03	4.5E-03	3.8E-03
Naphthalene	4.83E-04	128	1125.00	11.73	7.72	10.43	1.5E+00	2.4E+00	6.0E+01	5.8E+01	4.9E+01
C11 to C22		150	1039.23	10.83							

Drinking Water: Table DW-8
Definitions and Exposure Factors

Vlookup Version v0705

Parameter	Value	Units	Notes
ELCR - Excess Lifetime Cancer Risk	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
HI - Hazard Index	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
CSF - Cancer Slope Factor	chemical specific	$(mg/kg\text{-}day)^{-1}$	see Table DW-9
URF - Unit Risk Factor	chemical specific	$(\mu g/m^3)^{-1}$	see Table DW-9
RfD - Reference Dose	chemical specific	mg/kg-day	see Table DW-9
RfC - Reference Concentration	chemical specific	$\mu g/m^3$	see Table DW-9
LADD - Lifetime Average Daily Dose	chemical specific	mg/kg-day	Pathway specific. See Table DW-2
LADE - Lifetime Average Daily Exposure	chemical specific	$\mu g/m^3$	see Table DW-2
ADD - Average Daily Dose	chemical specific	mg/kg-day	Pathway specific. See Table DW-3.
ADE - Average Daily Exposure	chemical specific	$\mu g/m^3$	Pathway specific. See Table DW-3.
EPC - Exposure Point Concentration	chemical specific	µg/L	see Table DW-1
$VI_{(1-8)}$ - Volume Ingested for age group 1-8	1	L/day	MADEP. 1995. Guidance for Disposal Site Risk Characterization. Appendix B-9.
$VI_{(8-15)}$ - Volume Ingested for age group 8-15	2	L/day	Ibid
$VI_{(15-31)}$ - Volume Ingested for age group 15-31	2	L/day	Ibid
RAF_c - Relative Absorption Factor for Cancer Effects	chemical specific	dimensionless	Pathway specific
EF - Exposure Frequency	1	event/day	
$ED_{ing,derm}$ - Exposure Duration for ingestion or dermal exposure	1	day/event	
ED_{inh} - Exposure Duration for inhalation exposure for age group 1-8	0.046	day/event	Calculated: Total time in shower room for a 1 - 8 year old (65.7 min) / day (1440 min).
ED_{inh} - Exposure Duration for inhalation exposure for age group 8-15	0.046	day/event	Calculated: Total time in shower room for a 8 - 15 year old (66.4 min) / day (1440 min)
ED_{inh} - Exposure Duration for inhalation exposure for age group 15-31	0.044	day/event	Calculated: Total time in shower room for a 15 - 31 year old (62.8 min) / day (1440 min)
$EP_{(1-8)}$ - Exposure Period for age group 1-8	7	years	
$EP_{(8-15)}$ - Exposure Period for age group 8-15	7	years	
$EP_{(15-31)}$ - Exposure Period for age group 15-31	16	years	
$BW_{(1-8)}$ - Body Weight for age group 1-8	17	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7, females.
$BW_{(8-15)}$ - Body Weight for age group 8-15	39.9	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7, females.
$BW_{(15-31)}$ - Body Weight for age group 15-31	58.7	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7, females.
$AP_{(lifetime)}$ - Averaging Period for lifetime	70	years	
$AP_{(noncancer)}$ - Averaging Period for noncancer	7	years	
IEC_S - Inhalation Exposure Concentration from showering	chemical specific	mg/m^3	Age group specific. See Table GW-8.
DA - Dose Absorbed through skin in shower	chemical specific	mg/cm^2	Age group specific. See Table GW-9.
OAE_c - Oral Absorption Efficiency for Cancer Effects	chemical specific	dimensionless	
$SA_{(1-8)}$ - Surface Area for age group 1-8	7130	cm^2	50th percentile for females. Appendix Table B-2. MADEP. 1995. Guidance for Disposal Site Risk Characterization.
$SA_{(8-15)}$ - Surface Area for age group 8-15	12800	cm^2	50th percentile for females. Appendix Table B-2. MADEP. 1995. Guidance for Disposal Site Risk Characterization.
$SA_{(15-31)}$ - Surface Area for age group 15-31	16731	cm^2	50th percentile for females. Appendix Table B-2. MADEP. 1995. Guidance for Disposal Site Risk Characterization.
D_s - Shower Duration for age group 1-8	45.7 0.76	min hour	U.S. EPA. 1997. Exposure Factors Handbook. Table 15-21. 95th percentile ages 1-8. Weighted average of 1-8 year age groups: ((4x50)+(3x40))/7= 45.7 minutes
D_t - Total Time in Shower Room for age group 1-8	65.7	min	U.S. EPA. 1997. Exposure Factors Handbook. Tables 15-21,22. Equals the shower duration (Ds) plus the number of minutes spent in the shower room immediately after showering (95th percentile): Ds + ((4*20)+(3*20))/7 = 65.7 minutes
D_s - Shower Duration for age group 8-15	42.1 0.70	min hr	U.S. EPA. 1997. Exposure Factors Handbook. Table 15-21. 95th percentile ages 8-15. Weighted average of 8-15 age groups: ((4x40)+(3x45)/7 = 42.1 minutes
D_t - Total Time in Shower Room for age group 8-15	66.4	min	U.S. EPA. 1997. Exposure Factors Handbook. Tables 15-21,22. Equals the shower duration (Ds) plus the number of minutes spent in the shower room immediately after showering (95th percentile): Ds + ((4*20)+(3*30))/7=66.4 minutes
D_s - Shower Duration for age group 15-31	32.8 0.55	min hr	U.S. EPA. 1997. Exposure Factors Handbook. Table 15-21. 95th percentile ages 15-31. Weighted average of 15-31 year age groups: ((3x45)+(13x30)/16 = 32.8 minutes.
D_t - Total Time in Shower Room for age group 15-32	62.8	min	U.S. EPA. 1997. Exposure Factors Handbook. Tables 15-21,22. Equals the shower duration (Ds) plus the number of minutes spent in the shower room immediately after showering (95th percentile): Ds + ((3*30)+(13*30))/16 = 62.8 minutes
DM - Dermal Multiplier	chemical specific	dimensionless	If Kp < 0.5 cm/hr, then 0.2. Otherwise 1.

Drinking Water: Table DW-9
Chemical-Specific Data

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Oil or Hazardous Material	CSF $(mg/kg\text{-}day)^{-1}$	URF $(\mu g/m^3)^{-1}$	$RAF_{c\text{-}ing}$	OAE_c	RfD mg/kg-day	RfC mg/m^3	$RAF_{nc\text{-}ing}$	OAE_{nc}	DM	Molecular Weight g/mole	log K_{ow}	Permeability Coefficient Kp cm/hr	Henry's Law Constant HLC $atm\text{-}m^3/mol$
Benzene	5.5E-02	7.8E-06	1	1	4.0E-03	3.0E-02	1	1		78	2.13	1.55E-02	5.55E-03
Benzo(a)pyrene	7.3E+00	2.1E-03	1	0.92	3.0E-02	5.0E-02	0.91	0.92	1	252	6.1	7.51E-01	1.13E-06
Dichloroethylene, 1,1-					5.0E-02	2.0E-01	1	1					
Ethylbenzene					1.0E-01	1.0E+00	1	1					
Fluoranthene					4.0E-02	5.0E-02	1	0.92	0.2				
Hmx					5.0E-02	1.8E-01	1	0.3					
Indeno(1,2,3-cd)pyrene	7.3E-01	2.1E-04	1	0.92	3.0E-02	5.0E-02	0.91	0.92	1	276	6.58	1.16E+00	1.60E-06
Naphthalene					2.0E-02	3.0E-03	1	0.92					
C11 to C22					3.0E-02	5.0E-02	0.91	0.92					
Rdx	1.1E-01	3.1E-05	1	1	3.0E-03	1.1E-02	1	1		222.26	0.87	3.45E-04	1.20E-05
Toluene					2.0E-01	4.0E-01	1	1					
Trichloroethane, 1,1,2-	5.7E-02	1.6E-05	1	1	4.0E-03	7.4E-02	1	1		133	2.05	6.74E-03	9.13E-04
Trichloroethylene	1.1E-02	1.7E-06	1	1	2.0E-03	1.8E-01	1	1		131	2.42	1.22E-02	1.03E-02
Vinyl chloride	1.4E+00	8.8E-06	1.53	0.64	3.0E-03	1.0E-01	1	0.98		63	1.36	5.73E-03	2.70E-02
Xylenes (mixed isomers)					2.0E-01	6.0E-02	1	1					

Method 3 Risk Assessment for Resident Exposed to Chemicals in Soil - Shortform 2005 (sf05rs)

Index	This spreadsheet.
EPCs	Tabel RS-1: Select chemcials and enter Exposure Point Concentrations (EPCs) in this spreadsheet. Associated risks are presented to the right of the EPC.
C Eq	Table RS-2: Equations to calculate cancer risks.
NC Eq	Table RS-3: Equations to calculate noncancer risks.
Exp	Table RS-4: Definitions and exposure factors.
Produce	Table RS-5: Equations to calculate produce ingestion rate
Chem	Table RS-6: Chemical-specific data.

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Resident - Soil: Table RS-2
Equations to Calculate Cancer Risk for Resident (Age 1-31 years)

Cancer Risk from Ingestion

$$ELCR_{ing} = LADD_{ing(1\text{-}31)} * CSF$$

$$LADD_{ing(1\text{-}31)} = LADD_{ing(1\text{-}8)} + LADD_{ing(8\text{-}15)} + LADD_{ing(15\text{-}31)}$$

$$LADD_{ing(age\ group\ x)} = \frac{[OHM]_{soil} * IR_x * RAF_{c\text{-}ing} * EF_{ing} * ED * EP_x * C}{BW_x * AP_{lifetime}}$$

Cancer Risk from Dermal Absorption

$$ELCR_{derm} = LADD_{derm} * CSF$$

$$LADD_{derm(1\text{-}31)} = LADD_{derm(1\text{-}8)} + LADD_{derm(8\text{-}15)} + LADD_{derm(15\text{-}31)}$$

$$LADD_{derm(age\ group\ x)} = \frac{[OHM]_{soil} * SA_x * RAF_{c\text{-}derm} * SAF_x * EF_{derm} * ED * EP_x * C}{BW_x * AP_{lifetime}}$$

Cancer Risk from Homegrown Produce

$$ELCR_{produce} = LADD_{produce(1\text{-}31)} * CSF$$

$$LADD_{produce(1\text{-}31)} = LADD_{produce(1\text{-}8)} + LADD_{produce(8\text{-}15)} + LADD_{produce(15\text{-}31)}$$

$$LADD_{produce(age\ x)} = \frac{[OHM_{soil}] * PUF * PIR_x * RAF_{produce} * EF_{produce} * ED * EP_x * C}{BW_x * AP_{lifetime}}$$

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Parameter	Value	Units
CSF	OHM specific	$(mg/kg\text{-}day)^{-1}$
LADD	age/OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
$IR_{(1\text{-}8)}$	100	mg/day
$IR_{(8\text{-}15)}$	50	mg/day
$IR_{(15\text{-}31)}$	50	mg/day
$PIR_{(1\text{-}8)}$	12,099	mg/day
$PIR_{(8\text{-}15)}$	17,809	mg/day
$PIR_{(15\text{-}31)}$	24,420	mg/day
$RAF_{c\text{-}ing}$	OHM specific	dimensionless
$RAF_{c\text{-}derm}$	OHM specific	dimensionless
$RAF_{c\text{-}produce}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.41	event/day
$EF_{produce}$	1	event/day
ED	1	day/event
$EP_{(1\text{-}8)}$	7	years
$EP_{(8\text{-}15)}$	7	years
$EP_{(15\text{-}31)}$	16	years
C	0.000001	kg/mg
$BW_{(1\text{-}8)}$	17	kg
$BW_{(8\text{-}16)}$	39.9	kg
$BW_{(16\text{-}31)}$	58.7	kg
$AP_{(lifetime)}$	70	years
$SA_{(1\text{-}8)}$	2431	cm^2
$SA_{(8\text{-}15)}$	4427	cm^2
$SA_{(15\text{-}31)}$	5653	cm^2
$SAF_{(1\text{-}8)}$	0.35	mg/cm^2
$SAF_{(8\text{-}15)}$	0.14	mg/cm^2
$SAF_{(15\text{-}31)}$	0.13	mg/cm^2
PUF	OHM specific	dimensionless

Resident - Soil: Table RS-1
Exposure Point Concentration (EPC)
Based on Resident Ages 1-31 (Cancer) and 1-6 (Noncancer)

Vlookup Version v0705

ELCR (all chemicals) = 2.E-05
HI (all chemicals) = 5

Do not insert or delete any rows
Click on empty cell below and select OHM using arrow.

Oil or Hazardous Material	EPC (mg/kg)	$ELCR_{ingestion}$	$ELCR_{dermal}$	$ELCR_{vegetable}$	$ELCR_{total}$	Chronic HQ_{ing}	Chronic HQ_{derm}	Chronic $HQ_{vegetable}$	HQ_{total}
Acenaphthylene	1.0E+00					2.9E-05	6.8E-05		9.7E-05
Benzo(a)anthracene	2.0E+00	1.5E-07	1.1E-07		2.7E-07	4.5E-05	2.7E-05		7.2E-05
Benzo(a)pyrene	1.3E+01	9.9E-06	7.3E-06		1.7E-05	2.9E-04	1.8E-04		4.7E-04
Chromium(VI)	5.0E+00					4.0E-03	3.1E-03	1.1E-01	1.2E-01
Chrysene	2.0E+00	1.5E-08	1.1E-08		2.7E-08	4.5E-05	2.7E-05		7.2E-05
Fluoranthene	2.0E+00					4.3E-05	1.0E-04		1.5E-04
Indeno(1,2,3-cd)pyrene	3.0E+00	2.3E-07	1.7E-07		4.0E-07	6.8E-05	4.1E-05		1.1E-04
Lead	6.5E+01					1.0E-01	1.1E-02	4.6E+00	4.7E+00
Nickel	2.0E+00					2.4E-04	7.2E-04	2.7E-02	2.8E-02
Rdx	2.0E+00	8.2E-08	1.7E-07		2.5E-07	1.6E-03	2.7E-03		4.3E-03

Resident - Soil: Table RS-3
Equations to Calculate Noncancer Risk for Resident Child (Age 1-8 years)

Vlookup Version v0705

Noncancer Risk from Ingestion

$$HQ_{ing} = \frac{ADD_{ing}}{RfD}$$

$$ADD_{ing} = \frac{[OHM]_{soil} * IR * RAF_{ac\text{-}ing} * EF_{ing} * ED * EP * C}{BW * AP}$$

Noncancer Risk from Dermal Absorption

$$HQ_{derm} = \frac{ADD_{ing,derm}}{RfD}$$

$$ADD_{derm} = \frac{[OHM]_{soil} * SA * RAF_{ac\text{-}derm} * SAF * EF_{derm} * ED * EP * C}{BW * AP}$$

Noncancer Risk from Homegrown Produce

$$HQ_{produce} = \frac{ADD_{produce}}{RfD}$$

$$ADD_{produce} = \frac{[OHM_{soil}] * PUF * PIR * RAF_{produce} * EF * ED_{produce} * EP * C}{BW * AP}$$

Parameter	Value	Units
RfD	OHM specific	mg/kg-day
ADD	OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
IR	100	mg/day
PIR	12,099	mg/day
$RAF_{ac\text{-}ing}$	OHM specific	dimensionless
$RAF_{ac\text{-}derm}$	OHM specific	dimensionless
$RAF_{ac\text{-}produce}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.41	event/day
$EF_{produce}$	1	event/day
ED	1	day/event
EP	7	years
C	0.000001	kg/mg
BW	17	kg
AP	7	year
SA	2431	cm^2
SAF	0.35	mg/cm^2
PUF	OHM specific	dimensionless

Resident - Soil: Table RS-4
Definitions and Exposure Factors

Vlookup Version v0705

Parameter	Value	Units	Notes
ELCR - Excess Lifetime Cancer Risk	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
CSF - Cancer Slope Factor	chemical specific	$(mg/kg\text{-}day)^{-1}$	
URF - Unit Risk Factor	chemical specific	$(\mu g/m^3)^{-1}$	
LADD - Lifetime Average Daily Dose	chemical specific	mg/kg-day	Pathway specific
LADE - Lifetime Average Daily Exposure	chemical specific	$\mu g/m^3$	
HQ - Hazard Quotient	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
RfD - Reference Dose	chemical specific	mg/kg-day	see Table RS-6
RfC - Reference Concentration	chemical specific	mg/m^3	see Table RS-6
ADD - Average Daily Dose	chemical specific	mg/kg-day	Pathway specific
ADE - Average Daily Exposure	chemical specific	mg/m^3	
EPC - Exposure Point Concentration	chemical specific	µg/L	
$IR_{(1-8)}$ - Soil Ingestion Rate for age group 1-8	100	mg/day	MADEP. 2002. Technical Update: Calculation of an Enhanced Soil Ingestion Rate. (http://www.mass.gov/dep/ors/orspubs.htm)
$IR_{(8-15)}$ - Soil Ingestion Rate for age group 8-15	50	mg/day	Ibid
$IR_{(15-31)}$ - Soil Ingestion Rate for age group 15-31	50	mg/day	Ibid
$PIR_{(1-8)}$ = Produce Ingestion Rate for age group 1-8	12,099	mg/day	see Table RS-6
$PIR_{(8-15)}$ = Produce Ingestion Rate for age group 8-15	17,809	mg/day	see Table RS-6
$PIR_{(15-31)}$ = Produce Ingestion Rate for age group 15-31	24,420	mg/day	see Table RS-6
RAF_c - Relative Absorption Factor for Cancer Effects	chemical specific	dimensionless	
$EF_{ing,derm}$ - Exposure Frequency for ingestion or dermal exposure	0.41	event/day	
$EF_{produce}$ - Exposure Frequency for produce ingestion	1	event/day	
ED - Exposure Duration	1	day/event	
$EP_{(1-8)}$ - Exposure Period for age group 1-8	7	years	
$EP_{(8-15)}$ - Exposure Period for age group 8-15	7	years	
$EP_{(15-31)}$ - Exposure Period for age group 15-31	16	years	
$BW_{(1-8)}$ - Body Weight for age group 1-8	17	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7, females.
$BW_{(8-15)}$ - Body Weight for age group 8-15	39.9	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7, females.
BW_{10} - Body Weight for age group 15-31	58.7	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7, females.
$AP_{(lifetime)}$ - Averaging Period for lifetime	70	years	
$AP_{(noncancer)}$ - Averaging Period for noncancer	7	years	
$SA_{(1-8)}$ - Surface Area for age group 1-8	2431	cm^2	50th percentile of face (1/3 head), forearms, hands, lower legs, and feet for females MADEP. 1995. Guidance for Disposal Site Risk Characterization. Appendix Table B-2.
$SA_{(8-15)}$ - Surface Area for age group 8-15	4427	cm^2	50th percentile of face (1/3 head), forearms, hands, lower legs, and feet for females MADEP. 1995. Guidance for Disposal Site Risk Characterization. Appendix Table B-2.
$SA_{(15-31)}$ - Surface Area for age group 15-31	5653	cm^2	50th percentile of face (1/3 head), forearms, hands, lower legs, and feet for females MADEP. 1995. Guidance for Disposal Site Risk Characterization. Appendix Table B-2.
$SAF_{(1-8)}$. Surface Adherence Factor for age group 1-8	0.35		All SAFs developed for ShortForm according to procedure outlined in MA DEP Technical Update: Weighted Skin-Soil Adherence Factors, April 2002
$SAF_{(8-15)}$ - Surface Adherence Factor for age group 8-15	0.14		
$SAF_{(15-31)}$ - Surface Adherence Factor for age group 15-31	0.13		

Resident - Soil: Table RS-6
Homegrown Produce Ingestion Rate

Vlookup Version v0705

Data on mean produce ingestion rates (wet weight, ww) in the Northeast was obtained from the 1994-1996 Continuing Survey of Food Intakes by Individuals (USDA). Data for both genders were used for children under 6, while data for males was used for individuals 6 and older. The mean ingestion rates presented in the survey represent the arithmetic average of all individuals surveyed, regardless of whether or not they had consumed the produce item (e.g., an individual that did not consume the produce item was assigned a rate of 0 g/day). To determine the mean ingestion rate for individuals who ate each produce item, the ingestion rate for all individuals (consumers and nonconsumers) was divided by the percentage of individuals who ate the item (Table RS-6A). These mean ingestion rates for the produce consumers were summed to determine the total produce ingestion rate for each age-group and converted to dry weight assuming the produce items were all 90% water.

To convert mean ingestion rates for the age-groups studied in the survey to age-groups used in risk calculations, each age-group ingestion rate from the survey (i.e., 1 - 2 year olds, 3 - 5 year olds, 6 - 11 year olds, 12 - 19 year olds, and 20 - 39 year olds) was weighted according to the number of years spent in the risk calculation age group (i.e., 1 - 8 year olds, 8 - 15 year olds, and 15 - 31 year olds) (Table RS-6B). It was assumed that 25% of produce ingested was home-grown (Table RS-6C).

Table RS-6A

Age-groups studied in survey	White Potatoes: Ingetion Rate for All g/d (ww)	White Potatoes: % of individuals that consumed item.	White Potatoes: Ingetion Rate for Consumers g/d (ww)	Dark-green vegetables: Ingetion Rate for All g/d (ww)	Dark-green vegetables: % of individuals that consumed item.	Dark-green vegetables: Ingetion Rate for Consumers g/d (ww)	Deep-yellow vegetables: Ingetion Rate for All g/d (ww)	Deep-yellow vegetables: % of individuals that consumed item.	Deep-yellow vegetables: Ingetion Rate for Consumers g/d (ww)
1-2	28	40.3	69.5	6	10.1	59.4	5	12.7	39.4
3-5	30	37.1	80.9	5	6.5	76.9	7	12.7	55.1
6-11	47	44.2	106.3	6	9.1	65.9	2	8.5	23.5
12-19	59	40.3	146.4	2	2.3	87.0	11	15.8	69.6
20-39	76	45.1	168.5	25	14.7	170.1	4	5.7	70.2

Age-groups studied in survey	Tomatoes: Ingetion Rate for All g/d (ww)	Tomatoes: % of individuals that consumed item.	Tomatoes: Ingetion Rate for Consumers g/d (ww)	Lettuce: Ingetion Rate for All g/d (ww)	Lettuce: % of individuals that consumed item.	Lettuce: Ingetion Rate for Consumers g/d (ww)	Green Beans: Ingetion Rate for All g/d (ww)	Green Beans: % of individuals that consumed item.	Green Beans: Ingetion Rate for Consumers g/d (ww)
1-2	10	27.9	35.8	1	6	16.7	7	12.1	57.9
3-5	10	37.1	27.0	4	14	28.6	3	5.7	52.6
6-11	20	42	47.6	8	14.9	53.7	1	2	50.0
12-19	29	45.2	64.2	19	28.7	66.2	2	2.4	83.3
20-39	48	50.9	94.3	18	29.6	60.8	4	3.7	108.1

Table RS-6A (continued)

Age-groups studied in survey	Corn, Green peas, Lima beans: Ingetion Rate for All g/d (ww)	Corn, Green peas, Lima beans: % of individuals that consumed item.	Corn, Green peas, Lima beans: Ingetion Rate for Consumers g/d (ww)	Melons, berries: Ingetion Rate for All g/d (ww)	Melons, berries: % of individuals that consumed item.	Melons, berries: Ingetion Rate for Consumers g/d (ww)	Totals Wet Weight WWI g/day	Totals Dry Weight DWI g/day
1-2	12	15	80.0	7	9	77.8	436.4	43.6
3-5	14	21.7	64.5	14	11.6	120.7	506.3	50.6
6-11	9	13.6	66.2	5	5.9	84.7	498.0	49.8
12-19	14	9.9	141.4	17	5	340.0	998.1	99.8
20-39	12	7.3	164.4	6	4.5	133.3	969.7	97.0

Table RS-6B

Age-groups studied in survey	Years spent in age-group for 1-8 year old	Years spent in age-group for 8-15 year old	Years spent in age-group for 15-31 year old
1-2	2		
3-5	3		
6-11	2	4	
12-19		3	4
20-39			12
	7	7	16

Table RS-6C

	Produce Intake, dry weight: Child 1-8 years g/day	Child 8-15 years g/day	Adult 15-31 g/day
All Produce:	48.4	71.2	97.7
Homegrown:	12.1	17.8	24.4

Resident - Soil: Table RS-6
Chemical-Specific Data

Vlookup Version v0705

Oil or Hazardous Material	CSF $(mg/kg\text{-}day)^{-1}$	$RAF_{c\text{-}ing}$	$RAF_{c\text{-}derm}$	$RAF_{c\text{-}produce}$	RfD mg/kg-day	$RAF_{ac\text{-}ing}$	$RAF_{ac\text{-}derm}$	$RAF_{ac\text{-}produce}$	PUF
Acenaphthylene					0.03	3.6E-01	1.0E-01		
Benzo(a)anthracene	7.3E-01	2.8E-01	2.0E-02		0.03	2.8E-01	2.0E-02		
Benzo(a)pyrene	7.3E+00	2.8E-01	2.0E-02		0.03	2.8E-01	2.0E-02		
Chromium(VI)					0.003	1.0E+00	9.0E-02	1	0.1
Chrysene	7.3E-02	2.8E-01	2.0E-02		0.03	2.8E-01	2.0E-02		
Fluoranthene					0.04	3.6E-01	1.0E-01		
Indeno(1,2,3-cd)pyrene	7.3E-01	2.8E-01	2.0E-02		0.03	2.8E-01	2.0E-02		
Lead					0.00075	5.0E-01	6.0E-03	0.5	0.15
Nickel					0.02	1.0E+00	3.5E-01	1	0.38
Rdx	1.1E-01	1.0E+00	2.0E-01		0.003	1.0E+00	2.0E-01		