White Paper:
Generic Exposure Pathway Assumptions and Data Sources

May 2014

Prepared for
The Part 201 Stakeholder Group

Prepared by
Public Sector Consultants Inc.
Lansing, Michigan
www.pscinc.com

In collaboration with
Michigan Department of Environmental Quality
Lansing, Michigan

INTRODUCTION AND BACKGROUND

Exposure pathway means the route through which a human or biota may come into contact with a contaminant. The five elements of an exposure pathway are (1) the source of contamination, (2) the environmental media and transport mechanism, (3) the point of exposure, (4) the route of exposure, and (5) the receptor population. These elements of an exposure pathway may be based on past, present, or future events.[1]

The overall purpose of an exposure assessment is to evaluate and document how people might be exposed to site-related contaminants, and to identify and characterize the potentially exposed population(s) in the present and reasonably anticipated future use of the site. Remedial investigations attempt to develop a general understanding of a contaminated site and to evaluate potential human exposure pathways and impacts to the environment. It should be noted that site screening levels (SSLs) established to carry out exposure assessments are not utilized as final cleanup criteria. Where contaminant concentrations equal or exceed the SSLs, further study or investigation, but not necessarily cleanup, is warranted.

An exposure assessment identifies areas of concern and chemicals of concern, evaluates actual or potential exposure pathways, and characterizes the potentially exposed receptors (residents, workers, recreational users, etc.). This assists in identifying and setting priorities for the remediation activities to be conducted. In addition, the exposure assessment must consider the nature of populations currently exposed or that have the potential to be exposed to site-related contaminants both on- and off-site, and must describe the reasonably anticipated future land use of the site and affected off-site areas. Consequently, in addition to collection of on-site data, some off-site field investigation may be necessary to identify and sample any potential areas of contamination in support of the exposure assessment.

Descriptive exposure assessments seek to describe the ongoing risks from measurable exposures in an actual setting. Examples of descriptive exposure assessments are those intended to characterize workplace risks, or the risk to consumers of specific species of contaminated fish from a specific water body. Although the exposures in such cases are theoretically measurable on a real-time and individual basis, it is more common for exposures to be characterized by temporally and geographically discrete sampling of the environment, or by using generic exposure assumptions such as the ones discussed above.

In contrast, predictive exposure assessments seek to predict the exposures that will occur under a future or hypothetical set of exposure conditions. Examples of predictive exposure assessments are those intended to assist in setting generic acceptable levels of a contaminant in drinking water or in soil. Since these exposures are not occurring in the present, they cannot be measured, and so must be predicted under a specific exposure scenario generally using data obtained from the scientific literature. In such cases, the exposure assessment is required to quantitatively characterize those aspects of the scenario that determine the dose. This is generally accomplished with a model that integrates the dose over time to predict the cumulative dose.

Such models required identification of the relevant routes of exposure (ingestion, inhalation, dermal absorption), the receptors (children, adults, workers, pregnant women, etc.), the concentration of the contaminant in the relevant media (soil, air, water, and food), the uptake or intake rate for each medium (for example, grams of soil ingested per day, cubic meters of air inhaled per day, liters of water ingested per day), the frequency of exposure (continuous, daily, monthly, etc.), the duration of exposure (lifetime, childhood, occupational lifetime, single day, gestation, etc.), and factors such as the bioavailability of the substance in the particular medium that can alter the nominal dose.[2] Such scenarios, even when realistic,

[1] New York State Department of Environmental Conservation, May 3, 2010, *DER-10/Technical Guidance for Site Investigation and Remediation.* Available http://www.dec.ny.gov/docs/remediation_hudson_pdf/der10.pdf (accessed 4/23/14).
[2] National Research Council, , *Human Exposure Assessment for Airborne Pollutants* (Washington, D.C.: National Academy Press, 1991).

are often based on assumed or hypothetical populations with typical activity patterns. Generic parameters for common activities associated with environmental exposures can be found in the *Exposure Factors Handbook* published by the U.S. Environmental Protection Agency (EPA).

When generic exposure assumptions are used, point estimates (single numerical values) have traditionally been assigned to each exposure variable (for example, the volume of daily water consumption). Recognizing, however, that each variable can assume a range of possible values, attempts have been made to select upper percentiles for some exposure variables so as to be inclusive of most of the potentially exposed population. Such values can often be located in the EPA's *Exposure Factors Handbook*.[3]

Over the last several decades, probabilistic (largely Monte Carlo) approaches have been proposed to address the underlying variability and uncertainty in exposure assessment. Such approaches allow for realistic descriptions of the full range of exposure variables and yield a distributional description of the integrated exposure estimate. This distributional description of the overall exposure estimate allows risk managers to select the exposure and related risk at a specific percentile of the estimated population distribution (e.g., 90th, 95th, 99th upper percentile of exposure) for a given exposure scenario. Probabilistic approaches, therefore, hold the potential for more realistic (if still generic) exposure assessment. Regulatory agencies, however, have been slow to accept such approaches. In part, this is because the probabilistic description of many key exposure patterns is uncertain. This uncertainty stems from the lack of information about the specifics of distributions, particularly in their extreme values. Another factor contributing to the slow adoption of probabilistic approaches is that differences among populations, including regional and ethnic differences, make the derivation of generic distributions difficult since different populations may not lie on the same continuous distribution.

When dealing with the suite of exposure variables in an exposure model, however, the mathematical combination of upper percentile values in the exposure model together can quickly compound into an extreme upper percentile estimate of the overall exposure. This has been referred to as *redundant* or *compounding conservatism*.[4] Various combinations of central tendency estimates and upper percentiles have been proposed to remedy this situation, but such approaches are necessarily arbitrary, and result in exposure estimates with an unknown degree of population inclusiveness. These problems arise because no single value can adequately represent variables that are, in fact, distributed quantities.[5]

In practice, the selection of numeric values used to represent the many assumptions that go into defining exposure to environmental contaminants is based upon a combination of the availability of scientific data, best practices, and policy decisions to model the most realistic exposure. As mentioned previously, no single value can effectively represent an exposure variable for all exposure scenarios. Rather, a reasonable and relevant exposure scenario is defined and assumptions regarding the exposure variables are made to best represent that scenario.

Michigan's Part 201 criteria are based on either the generic risk-based (health) or the default criteria established by the Part 201 statute or the administrative rules. Carcinogenic and/or non-carcinogenic risk-based values are calculated using the algorithms presented in the rules for each Part 201 hazardous substance for each exposure pathway where the complete information is available to the Michigan Department of Environmental Quality to do so (see Appendix A). The risk-based numeric values may or may not represent the Part 201 generic criteria, depending on the specific exposure pathway and

[3] U.S. Environmental Protection Agency, *Exposure Factors Handbook*, EPA/600/C-99/001 (Washington, D.C.: National Center for Environmental Assessment, 1999).
[4] D. E. Burmaster and R.E. Harris, 1993, The magnitude of compounding conservatism in superfund risk assessments, *Risk Analysis* 13: 131–134.
[5] U.S. Environmental Protection Agency, *Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual (Part A) Interim Final,* EPA/540/01-89/002 (Washington, D.C.: EPA, Office of Emergency and Remedial Response, December 1989), http://www.epa.gov/oswer/riskassessment/ragsa/pdf/rags_a.pdf (accessed 4/23/14)

additional requirements established in both the Part 201 statute and rule language. For example, the residential risk-based value for arsenic in drinking water is 0.57 ug/L, but 20120a(5) states that the state drinking water standard (i.e., 10 ug/L) shall be the final criterion. As such, this document specifically addresses the department's development of the calculated risk-based generic values for the Part 201 hazardous substances, not the final cleanup criteria.

In its development of generic cleanup criteria, the MDEQ has made decisions regarding human health risk assessment assumptions using EPA risk assessment guidance, in collaboration with stakeholders, using professional judgment, and based on policy decisions at the time. The numeric values that were ultimately selected using this process were promulgated in the Part 201 cleanup criteria rules. Since these values were first published in the Administrative Rules in 2002, the scientific database supporting many of these assumptions has expanded. New guidance, more comprehensive data, and improved mathematic models are now available resources with which to evaluate whether the existing values continue to best represent each of the MDEQ's exposure assumptions. However, even if a new selection process is established and more representative values are identified, the concept of a single value representing a range of possible values remains problematic. The option to develop site-specific criteria avoids this reliance on generic exposure assumptions by allowing the user to more accurately represent exposure conditions at their site through collection of site-specific data. It should also be noted that several of the exposures allow adjustments of select factors (e.g., soil type) on a facility-specific basis to better reflect actual facility conditions, and yet be labeled as a "generic criteria." These are usually included for parameters that have a wide disparity of values that can be measured or assumed at a facility. For many exposures, the department has formerly published numerous documents (i.e., Operations Memos and Technical Support documents) that describe the process and basis for selecting endpoints. These documents can be accessed at:

- http://michigan.gov/deq/0,4561,7-135-3311_4109_9846-101581--,00.html

Appendices B, C, and D show the comparison of values for Michigan with EPA and Region 5 state agencies exposure assumptions, data sources, and values for:

- Drinking water pathway
- Soil pathway
- All pathways

For these three spreadsheets, the EPA has recently released new recommendations for default exposure factors based on the 2011 *EPA Exposure Factors Handbook*. These values (such as 80 kg average adult weight) have not yet been incorporated into the EPA risk screening levels (RSLs) listed in these three tables; however, they most likely will be incorporated sometime this year. EPA recommendations can be found in Appendix E.

Lastly, Appendices F and G provide a comparison of drinking water criteria and soil contact criteria that highlight receptors, pathways, land uses, and the toxicity basis for the criteria/RSLs used in Michigan, EPA, and Region 5 states, which will be helpful when attempting to answer the questions listed below.

QUESTIONS FOR THE TECHNICAL ADVISORY GROUP

The Technical Advisory Group (TAG) is being asked to review and address the following questions and issues:

Land Uses: Residential and Nonresidential

1. The current criteria utilize adults only as the receptor for residential drinking water, and adults plus children (age-adjusted) as the receptor for direct soil contact. Should the age-dependent adjustment factors (ADAFs) recommended by the EPA be used to address early life exposure from mutagenic carcinogens? The ADAFs would be applied to those substances that have been identified by the EPA to be mutagenic carcinogens (approximately 10 substances on the current Part 201 list of hazardous substances and cleanup criteria).
2. What is the most appropriate nonresidential scenario for workers, that is, indoor, outdoor, or a combination of both?

Data Sources/References

1. What are the appropriate data sources for the estimates for exposure assumptions such as drinking water ingestion rates, soil ingestion rates, body weights for the selected age groups, relative source contribution factors, chemical-specific dermal absorption factors, and other dermal exposure assumptions?
2. What are the appropriate data sources for and estimates of exposure frequency, exposure duration, and averaging time?
3. Where available, should the department utilize Michigan-specific, rather than nationally representative, data? If so, which data should be utilized?
4. Should the "algorithms, exposure assumptions" be consistent with or based upon federal (i.e., U.S. EPA) methodology and data? If yes, are there any circumstances under which deviations from the federal methodology and data should be allowed?
5. In totality, are the pathways, models and cumulative exposure assumptions reflective of "reasonable and relevant pathways, best science, and realistic conditions?"

Numeric Values: Exposure Assumptions

1. Based on the identified receptors and routes of exposure, what are reasonable values and data sources to use for the various assumptions?
2. Given the range of exposure assumption values, how should the most appropriate number be selected?
3. When are data of sufficient quality available for a Monte Carlo analysis and other probabilistic methods to be performed to derive all or part of the factors used in an exposure assessment for one or more exposure pathways?
4. For each pathway calculation recommended, has it been determined to be *reasonable and relevant,* and has a final check of the suite of parameters been performed to ensure that modeled exposures are not unduly protective due to *compounding conservatism*?

Note: Some of the exposure assumptions identified within this group can be carried over to TAG # 3 (vapor intrusion).

Appendix A:
Risk based Values

PART 201 DRINKING WATER AND SOIL CLEANUP CRITERIA EQUATIONS

Drinking Water Criteria (DWC) Equations (R 299.34)

Equation for Carcinogens:

$$DWC = \frac{TR \times BW \times AT \times CF}{SF \times EF \times ED \times IR_{dw}}$$

where,

DWC	(Drinking water criterion)	=	chemical-specific (ug/L or ppb)
TR	(Target risk level)	=	10^{-5}
BW	(Body weight)	=	70 kg
AT	(Averaging time in days)	=	25,550 days (70 years x 365 days/year)
CF	(Conversion factor)	=	1,000 ug/mg
SF	(Oral cancer slope factor)	=	chemical-specific $(mg/kg\text{-}day)^{-1}$
EF	(Exposure frequency)	=	350 days/year (residential)
		=	245 days/year (nonresidential)
ED	(Exposure duration)	=	30 years (residential)
		=	21 years (nonresidential)
IR_{dw}	(Drinking water ingestion rate)	=	2 liters/day (residential)
		=	1 liter/day (nonresidential)

Equation for Non-carcinogens:

$$DWC = \frac{THQ \times RfD \times BW \times AT \times RSC \times CF}{EF \times ED \times IR_{dw}}$$

where,

DWC	(Drinking water criterion)	=	chemical-specific (ug/L or ppb)
THQ	(Target hazard quotient)	=	1
RfD	(Oral reference dose)	=	chemical-specific (mg/kg-day)
BW	(Body weight)	=	70 kg
AT	(Averaging time)	=	10,950 days (30 years x 365 days/year - residential) 7,665 days (21 years x 365 days/year - nonresidential)
RSC	(Relative source contribution)	=	chemical-specific or 0.2 if chemical-specific data are not available
CF	(Conversion factor)	=	1,000 ug/mg
EF	(Exposure frequency)	=	350 days/year (residential) 245 days/year (nonresidential)
ED	(Exposure duration)	=	30 years (residential) 21 years (nonresidential)
IR_{dw}	(Drinking water ingestion rate)	=	2 liters/day (residential) 1 liter/day (nonresidential)

Soil Direct Contact Criteria (DCC) Equations (R 299.20)

Residential Equation for Carcinogens:

$$DCC = \frac{TR \times AT \times CF}{SF \times [(EF_i \times IF \times AE_i) + (EF_d \times DF \times AE_d)]}$$

where,

DCC	(Direct contact criterion)	=	chemical-specific, ug/kg or ppb
TR	(Target risk level)	=	10^{-5}
AT	(Averaging time)	=	25,550 days (70 years x 365 days/year)
CF	(Conversion factor)	=	1E+9 ug/kg
SF	(Oral cancer slope factor)	=	chemical-specific $(mg/kg\text{-}day)^{-1}$
EF_i	(Ingestion exposure frequency)	=	350 days/year
IF	(Age-adjusted soil ingestion factor)	=	114 mg-year/kg-day*
AE_i	(Ingestion absorption efficiency)	=	chemical-specific or default specified at R 299.20(3)
EF_d	(Dermal exposure frequency)	=	245 days/year
DF	(Age-adjusted soil dermal factor)	=	353 mg-year/kg-day**
AE_d	(Dermal absorption efficiency)	=	chemical-specific or default specified at R 299.20(3)

Residential Equation for Non-carcinogens:

$$DCC = \frac{THQ \times RfD \times AT \times CF \times RSC}{[(EF_i \times IF \times AE_i) + (EF_d \times DF \times AE_d)]}$$

where,

DCC	(Direct contact criterion)	=	chemical-specific (ug/kg or ppb)
THQ	(Target hazard quotient)	=	1
RfD	(Oral reference dose)	=	chemical-specific mg/kg-/day
AT	(Averaging time)	=	10,950 days (30 years x 365 days/year)
CF	(Conversion factor)	=	1E+9 ug/kg
RSC	(Relative source contribution)	=	1
EF_i	(Ingestion exposure frequency)	=	350 days/year
IF	(Age-adjusted soil ingestion factor)	=	114 mg-year/kg-day*
AE_i	(Ingestion absorption efficiency)	=	chemical-specific or default specified at R 299.20(3)
EF_d	(Dermal exposure frequency)	=	245 days/year
DF	(Age-adjusted soil dermal factor)	=	353 mg-year/kg-day**
AE_d	(Dermal absorption efficiency)	=	chemical-specific or default specified at R 299.20(3)

$$*IF = \left(\frac{IR_{age\ 1\text{–}6} \times ED_{age\ 1\text{–}6}}{BW_{age\ 1\text{–}6}}\right) + \left(\frac{IR_{adult} \times ED_{adult}}{BW_{adult}}\right)$$

where,

$IR_{soil/age\ 1\text{-}6}$	(Soil ingestion rate)	=	200 mg/day
$ED_{age\ 1\text{-}6}$	(Exposure duration)	=	6 years
$BW_{age\ 1\text{-}6}$	(Body weight)	=	15 kg
IR_{adult}	(Soil ingestion rate)	=	100 mg/day
ED_{adult}	(Exposure duration)	=	24 years
BW_{adult}	(Body weight)	=	70 kg

$$**DF = \left(\frac{SA_{age\ 1–6} \times EV \times AF_{age\ 1–6} \times ED_{age\ 1–6}}{BW_{age\ 1–6}}\right) + \left(\frac{SA_{adult} \times EV \times AF_{adult} \times ED_{adult}}{BW_{adult}}\right)$$

where,

$SA_{age\ 1-6}$	(Skin surface area)	=	2,670 cm^2/dayevent
EV	(Event frequency)	=	1 event/day
$AF_{age\ 1-6}$	(Soil adherence factor)	=	0.2 mg/cm^2
$ED_{age\ 1-6}$	(Exposure duration)	=	6 years
$BW_{age\ 1-6}$	(Body weight)	=	15 kg
SA_{adult}	(Skin surface area)	=	5,800 cm^2/dayevent
AF_{adult}	(Soil adherence factor)	=	0.07 mg/cm^2
ED_{adult}	(Exposure duration)	=	24 years
BW_{adult}	(Body weight)	=	70 kg

Nonresidential Equation for Carcinogens:

$$DCC = \frac{TR \times BW \times AT \times CF}{SF \times ED \times [(EF_i \times IR_s \times AE_i) + (EF_d \times SA \times EV \times AF \times AE_d)]}$$

where,

DCC	(Direct contact criterion)	=	chemical-specific, ug/kg or ppb
TR	(Target risk level)	=	10^{-5}
BW	(Body weight)	=	70 kg
AT	(Averaging time)	=	25,550 days (70 years x 365 days/year)
CF	(Conversion factor)	=	1E+9 ug/kg
SF	(Oral cancer slope factor)	=	chemical-specific $(mg/kg\text{-}day)^{-1}$
ED	(Exposure duration)	=	21 years
EF_i	(Ingestion exposure frequency)	=	245 days/year
IR_s	(Soil ingestion rate)	=	100 mg/day (residential)
AE_i	(Ingestion absorption efficiency)	=	chemical-specific or default specified at R 299.20(3)
EF_d	(Dermal exposure frequency)	=	160 days/year
SA	(Skin surface area)	=	3,300 cm^2/day event
EV	(Event frequency)	=	1 event/day
AF	(Soil adherence factor)	=	0.2 mg/cm^2 (nonresidential)
AE_d	(Dermal absorption efficiency)	=	chemical-specific or default specified at R 299.20(3)

Nonresidential Equation for Non-carcinogens:

$$DCC = \frac{THQ \times RfD \times BW \times AT \times CF \times RSC}{ED \times [(EF_i \times IR_s \times AE_i) + (EF_d \times SA \times EV \times AF \times AE_d)]}$$

where,

DCC	(Direct contact criterion)	=	chemical-specific, ug/kg or ppb
THQ	(Target hazard quotient)	=	1
RfD	(Oral reference dose)	=	chemical-specific, mg/kg-/day
BW	(Body weight)	=	70 kg
AT	(Averaging time)	=	7,665 days (21 years x 365

			days/year)
CF	(Conversion factor)	=	1E+9 ug/kg
RSC	(Relative source contribution)	=	1
ED	(Exposure duration)	=	21 years
EF_i	(Ingestion exposure frequency)	=	245 days/year
IR_s	(Soil ingestion rate)	=	100 mg/day
AE_i	(Ingestion absorption efficiency)	=	chemical-specific or default specified at R 299.20(3)
EF_d	(Dermal exposure frequency)	=	160 days/year
SA	(Skin surface area)	=	3,300 cm^2/day event
EV	(Event frequency)	=	1 event/day
AF	(Soil adherence factor)	=	0.2 mg/cm^2 (nonresidential)
AE_d	(Dermal absorption efficiency)	=	chemical-specific or default specified at R 299.20(3)

Cleanup Criteria Based on Ambient Air Inhalation of Volatiles or Particulates in Soil (VSIC, PSIC) Equations (R 299.26)

Residential Equations for Carcinogens:

$$VSIC = \frac{TR \times AT}{IURF \times EF \times ED \times (1/VF)}$$

where,

VSIC	(Volatile soil inhalation criterion)	=	chemical-specific, ug/kg or ppb
TR	(Target risk level)	=	10^{-5}
AT	(Averaging time)	=	25,550 days (70 years x 365 days/year)
IURF	(Inhalation unit risk factor)	=	chemical-specific $(ug/m^3)^{-1}$
EF	(Exposure frequency)	=	350 days/year
ED	(Exposure duration)	=	30 years
VF	(Volatilization factor)	=	chemical-specific, m^3/kg

$$PSIC = \frac{TR \times AT}{IURF \times EF \times ED \times (1/PEF)}$$

where,

PSIC	(Particulate soil inhalation criterion)	=	chemical-specific, ug/kg or ppb
TR	(Target risk level)	=	10^{-5}
AT	(Averaging time)	=	25,550 days (70 years x 365 days/year)
IURF	(Inhalation unit risk factor)	=	chemical-specific $(ug/m^3)^{-1}$
EF	(Exposure frequency)	=	350 days/year
ED	(Exposure duration)	=	30 years
PEF	(Particulate emission factor)	=	chemical-specific, m^3/kg

Residential Equations for Non-carcinogens:

$$VSIC = \frac{THQ \times AT}{EF \times ED \times (1/ITSL \times 1/VF)}$$

where,

VSIC	(Volatile soil inhalation criterion)	=	chemical-specific, ug/kg or ppb
THQ	(Target hazard quotient)	=	1
AT	(Averaging time)	=	10,950 days (30 years x 365 days/year)
EF	(Exposure frequency)	=	350 days/year

ED	(Exposure duration)	=	30 years
ITSL	(Initial threshold screening level)	=	chemical-specific, ug/m^3
VF	(Volatilization factor)	=	chemical-specific, m^3/kg

$$PSIC = \frac{THQ \times AT}{EF \times ED \times (1/ITSL \times 1/PEF)}$$

where,

PSIC	(Particulate soil inhalation criterion)	=	chemical-specific, ug/kg or ppb
THQ	(Target hazard quotient)	=	1
AT	(Averaging time)	=	10,950 days (30 years x 365 days/year)
EF	(Exposure frequency)	=	350 days/year
ED	(Exposure duration)	=	30 years
ITSL	(Initial threshold screening level)	=	chemical-specific, ug/m^3
PEF	(Particulate emission factor)	=	chemical-specific, m^3/kg

The volatilization factor (VF) shall be calculated based on the infinite equation (a). If the vertical extent of the contaminant source has been adequately characterized, then the VF shall be calculated either by the finite source equation (b) or the mass balance equation (c), whichever yields the highest VSIC:

(a) Infinite source model:

$$VF = (Q/C) \times (1/J_s^{ave})$$

$$J_s^{ave} = \rho_b (4D_A/\pi t)^{1/2} \times 10^4 \, cm^2/m^2$$

$$D_A = \frac{[(\theta_a^{3.33} D_a (H' \times TAF) + \theta_w^{3.33} D_w)/n^2]}{\rho_b K_d + \theta_w + \theta_a (H' \times TAF)}$$

where,

VF	(Volatilization factor)	=	chemical-specific, m^3/kg
J_s^{ave}	(Normalized average flux from soil)	=	chemical-specific, g/m^2-second
D_A	(Apparent diffusivity)	=	chemical-specific, cm^2/second
Q/C	(Dispersion factor for 1/2 acre)	=	82.33, g/m^2-second per kg/m^3
T	(Exposure time)	=	seconds (ED x 3.1536E+7 seconds/yr)
θ_a	(Soil air-filled porosity)	=	0.28 L_{air}/L_{soil}
N	(Total soil porosity)	=	0.43 L_{pore}/L_{soil}
θ_w	(Soil water-filled porosity)	=	0.15 L_{water}/L_{soil}
ρ_b	(Dry soil bulk density)	=	1.5 g/cm^3
D_a	(Diffusivity in air)	=	chemical-specific, cm^2/second
D_w	(Diffusivity in water)	=	chemical-specific, cm^2/second
H′	(Dimensionless Henry's Law Constant, where H′ = HLC x 41)	=	chemical-specific, unitless
HLC	(Henry's Law Constant at 25^0 C)	=	chemical-specific, atm-m^3/mol
TAF	(Temperature adjustment factor)	=	0.5
K_d	(Soil-water partition coefficient)	=	chemical-specific, cm^3/g
	For organic compounds	=	K_{oc} (cm^3/g) x f_{oc} (g/g)
	For inorganic compounds	=	chemical-specific, cm^3/g
K_{oc}	(Soil organic carbon partition coefficient)	=	chemical-specific, cm^3/g
f_{oc}	(Organic carbon content of soil)	=	0.006 g/g (0.6%)

(b) Finite source model:

$$VF = (Q/C) \times (C_0 / \rho_b) \times (1 / J_s^{ave})$$

$$J_s = C_o (D_A / \pi t)^{1/2} \left[1 - \exp\left(-d_s^2 / 4 D_A t\right)\right]$$

where,

VF	(Volatilization factor)	=	chemical-specific, m^3/kg
Q/C	(Dispersion factor for 1/2 acre)	=	82.33, g/m^2-second per kg/m^3
C_0	(Uniform contaminant concentration at t=0)	=	1.5 E-6 g/cm^3
ρ_b	(Dry soil bulk density)	=	1.5 g/cm^3
J_s^{ave}	(Normalized average flux from soil)	=	chemical-specific, g/m^2-second
J_s	(Instantaneous flux from soil at time t)	=	chemical-specific, g/m^2-second
D_A	(Apparent diffusivity—see equation above)	=	chemical-specific, cm^2/second
T	(Time)	=	seconds
d_s	(Thickness of source)	=	site-specific, meters
exp(p)	(The base of the natural logarithm raised to power (p))	=	e^p

(c) Mass balance VF:

$$VF = (Q/C) \times \frac{AT \times (3.15 \times 10^{-7} \text{ seconds/year})}{\rho_b \times d_s \times 10^6 \text{ g/Mg}}$$

where,

VF	(Volatilization factor)	=	chemical-specific, m^3/kg
Q/C	(Dispersion factor for 1/2 acre)	=	82.33, g/m^2-second per kg/m^3
AT	(Exposure period)	=	scenario-specific, years
ρ_b	(Dry soil bulk density)	=	1.5 mg/m^3
d_s	(Average source depth)	=	site-specific, meters

$$PEF = (Q/C) \times 1 / \left[(Ew \times (1 - V)) + Ev\right]$$

where,

PEF	(Particulate emission factor)	=	chemical-specific, m^3/kg
Q/C	(Dispersion factor for 1/2 acre)	=	82.33, g/m^2-second per kg/m^3
Ew	(Emission due to wind)	=	g/m^2 per second
Ev	(Emission due to vehicle traffic)	=	g/m^2 per second
V	(Vegetative cover)	=	0.5 (50%), unitless

Nonresidential Equations for Carcinogens:

$$VSIC = \frac{TR \times AT \times AIR}{IURF \times EF \times ED \times (1/VF)}$$

where,

VSIC	(Volatile soil inhalation criterion)	=	chemical-specific, ug/kg or ppb
TR	(Target risk level)	=	10^{-5}
AT	(Averaging time)	=	25,550 days (70 years x 365 days/year)

AIR	(Adjusted inhalation rate)	=	(20 m^3/day)/(10 m^3/day)
IURF	(Inhalation unit risk factor)	=	chemical-specific $(ug/m^3)^{-1}$
EF	(Exposure frequency)	=	245 days/year
ED	(Exposure duration)	=	21 years
VF	(Volatilization factor)	=	chemical-specific, m^3/kg

$$PSIC = \frac{TR \times AT \times AIR}{IURF \times EF \times ED \times (1/PEF)}$$

where,

PSIC	(Particulate soil inhalation criterion)	=	chemical-specific, ug/kg or ppb
TR	(Target risk level)	=	10^{-5}
AT	(Averaging time)	=	25,550 days (70 years x 365 days/year)
AIR	(Adjusted inhalation rate)	=	(20 m^3/day)/(10 m^3/day)
IURF	(Inhalation unit risk factor)	=	chemical-specific $(ug/m^3)^{-1}$
EF	(Exposure frequency)	=	245 days/year
ED	(Exposure duration)	=	21 years
PEF	(Particulate emission factor)	=	chemical-specific, m^3/kg

Nonresidential Equations for Non-carcinogens:

$$VSIC = \frac{THQ \times AT}{EF \times ED \times (1/ITSL \times 1/VF)}$$

where,

VSIC	(Volatile soil inhalation criterion)	=	chemical-specific, ug/kg or ppb
THQ	(Target hazard quotient)	=	1
AT	(Averaging time)	=	7,665 days (21 years x 365 days/year)
EF	(Exposure frequency)	=	245 days/year
ED	(Exposure duration)	=	21 years
ITSL	(Initial threshold screening level)	=	chemical-specific, ug/m^3
VF	(Volatilization factor)	=	chemical-specific, m^3/kg

$$PSIC = \frac{THQ \times AT}{EF \times ED \times (1/ITSL \times 1/PEF)}$$

where,

PSIC	(Particulate soil inhalation criterion)	=	chemical-specific, ug/kg or ppb
THQ	(Target hazard quotient)	=	1
AT	(Averaging time)	=	7,665 days (21 years x 365 days/year)
EF	(Exposure frequency)	=	245 days/year
ED	(Exposure duration)	=	21 years
ITSL	(Initial threshold screening level)	=	chemical-specific, ug/m^3
PEF	(Particulate emission factor)	=	chemical-specific, m^3/kg

The residential and nonresidential generic VSIC and PSIC are calculated for a source area size of 1/2 acre. The generic VSIC and PSIC shall be adjusted for other source area sizes by multiplying the generic SIC by the modifiers given in the following table.

Modifiers		
Source Size (ft^2 or acres)	Q/C (g/m^2-s per kg/m^3)	Modifier
400 ft^2	261.26	3.17
1000 ft^2	180.76	2.2
2000 ft^2	144.91	1.76
¼ acre	94.56	1.15
½ acre	82.33	1
1 acre	71.74	0.87
2 acres	63.51	0.77
5 acres	54.62	0.66
10 acres	49.13	0.6
32 acres	41.55	0.5
100 acres	35.66	0.43

PART 201 VOLATILIZATION TO INDOOR AIR INHALATION CRITERIA EQUATIONS (VAPOR INTRUSION)

Groundwater Volatilization to Indoor Air Inhalation Criteria Equations (GVIIC) (R 299.14)

Equation for Carcinogens:

$$GVIIC = \frac{TR \times AT \times AIR}{IURF \times EF \times ED \times CR_{building}}$$

where,

GVIIC	(Groundwater volatilization indoor air inhalation criteria)	= chemical-specific, ug/L
TR	(Target risk level)	= 10^{-5}
AT	(Averaging time)	= 25,550 days (70 x 365)
AIR	(Adjusted inhalation rate)	= 1 (residential) = 2 (nonresidential)
IURF	(Inhalation unit risk factor)	= chemical-specific, $(ug/m^3)^{-1}$
EF	(Exposure frequency)	= 350 days/year (residential) = 245 days/year (nonresidential)
ED	(Exposure duration)	= 30 years (residential) = 21 years (nonresidential)
$CR_{building}$	(Ratio of indoor air concentration to groundwater concentration)	= chemical-specific, $(ug/m^3)/(ug/L)$

Equation for Non-carcinogens:

$$GVIIC = \frac{THQ \times AT}{(1/ITSL) \times EF \times ED \times CR_{building}}$$

where,

GVIIC	(Groundwater volatilization indoor air inhalation criteria)	= chemical-specific, ug/L
THQ	(Target hazard quotient)	= 1
AT	(Averaging time)	= 10,950 days (residential) = 7,665 days (nonresidential)
EF	(Exposure frequency)	= 350 days/year (residential) = 245 days/year (nonresidential)
ED	(Exposure duration)	= 30 years (residential) = 21 years (nonresidential)
ITSL	(Initial threshold screening level)	= chemical-specific, ug/m^3
$CR_{building}$	(Ratio of indoor air concentration to groundwater concentration)	= chemical-specific, (ug/m^3)/(ug/L)

$$CR_{building} = CR_{source}^{gw} \times \alpha$$

where,

$CR_{building}$	(Ratio of indoor air concentration to groundwater concentration)	= chemical-specific, (ug/m^3)/(ug/L)
α	(Attenuation coefficient)	= chemical-specific, unitless
CR_{source}^{gw}	(Ratio of soil vapor concentration to groundwater/source concentration)	= chemical-specific, (ug/m^3)/(ug/L)

$$CR_{source}^{gw} = H' \text{ x } TAF \times C_w \times 10^3 \text{ L/m}^3$$

where,

CR_{source}^{gw}	(Ratio of soil vapor concentration to groundwater/source concentration)	= chemical-specific, (ug/m^3)/(ug/L)
H’	(Dimensionless Henry’s law constant, where H’ = HLC x 41)	= chemical-specific, unitless
HLC	(Henry’s law constant at 25 degrees Celsius)	= chemical-specific, (atm-m^3/mol)
TAF	(Temperature adjustment factor)	= 0.5, unitless
C_w	(Uniform unit groundwater concentration)	= 1 ug/L

$$\alpha = \frac{\left[\left[\frac{D_T^{eff} A_b}{Q_{building} L_T}\right] \times \exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right)\right]}{\left[\exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) + \left[\frac{D_T^{eff} A_b}{Q_{building} L_T}\right] + \left[\frac{D_T^{eff} A_b}{Q_{soil} L_T}\right]\left[\exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) - 1\right]\right]}$$

where,

α	(Attenuation coefficient)	= unitless
D_T^{eff}	(Total effective diffusion coefficient)	= chemical-specific, cm^2/s
D^{crack}	(Effective diffusion coefficient through crack)	= cm^2/s, ($D^{crack} = D_v^{eff}$, see equation for D_v^{eff} below)
A_b	(Area of enclosed space below grade)	= 1.96E+6 cm^2 (residential) = 3.83E+6 cm^2 (nonresidential)

$Q_{building}$	(Building ventilation rate)	= 1.51E+5 cm^3/s (residential) = 5.04E+5 cm^3/s (nonresidential)
L_{crack}	(Building foundation thickness)	= 15 cm
L_T	(Source-building separation distance)	= 115 cm (residential) = 300 cm (nonresidential)
Q_{soil}	(Volumetric flow rate of soil vapor into the building)	= 0.81 cm^3/s (residential) = 2.10 cm^3/s (nonresidential)
A_{crack}	(Total area of cracks below grade)	= 196 cm^2 (residential) = 383 cm^2 (nonresidential)
exp(p)	(The base of the natural logarithm raised to power p)	= e^p

$$D_T^{eff} = \frac{L_T}{\left[\left(h_v + L_{crack}\right)/D_v^{eff}\right] + \left(h_{cf}/D_{cf}^{eff}\right)}$$

where,

D_T^{eff}	(Total effective diffusion coefficient)	= chemical-specific, cm^2/s
L_T	(Source-building separation distance)	= 115 cm (residential) = 300 cm (nonresidential)
h_v	(Thickness of vadose zone below enclosed space floor)	= 75 cm (residential) = 260 cm (nonresidential)
L_{crack}	(Building foundation thickness)	= 15 cm
D_v^{eff}	(Effective diffusion coefficient through vadose zone)	= chemical-specific, cm^2/s
h_{cf}	(Thickness of capillary fringe)	= 25 cm
D_{cf}^{eff}	(Effective diffusion coefficient through capillary fringe)	= chemical-specific, cm^2/s

$$D_v^{eff} = \left[D_a\left(\theta_a^{3.33}/n^2\right)\right] + \left[\frac{D_w}{H' \times TAF}\left(\theta_w^{3.33}/n^2\right)\right]$$

where,

D_v^{eff}	(Effective diffusion coefficient through vadose zone)	= chemical-specific, cm^2/s
D_a	(Diffusivity in air)	= chemical-specific, cm^2/s
θ_a	(Soil air-filled porosity)	= 0.13 cm^3/cm^3
N	(Total soil porosity)	= 0.43 cm^3/cm^3
D_w	(Diffusivity in water)	= chemical-specific, cm^2/s
H'	(Dimensionless Henry's law constant, where H' = HLC x 41)	= chemical-specific, unitless
HLC	(Henry's law constant	= chemical-specific, (atm-m^3/mol)
TAF	(Temperature adjustment factor)	= 0.5
θ_w	(Soil water-filled porosity)	= 0.3 cm^3/cm^3

$$D_{cf}^{eff} = \left[D_a\left(\theta_{a,cf}^{3.33}/n^2\right)\right] + \left[\frac{D_w}{H' \times TAF}\left(\theta_{w,cf}^{3.33}/n^2\right)\right]$$

where,

D_{cf}^{eff}	(Effective diffusion coefficient through capillary fringe)	= chemical-specific, cm^2/s
D_a	(Diffusivity in air)	= chemical-specific, cm^2/s
$\theta_{a,cf}$	(Soil air-filled porosity in capillary fringe)	= 0.078 cm^3/cm^3
D_w	(Diffusivity in water)	= chemical-specific, cm^2/s

H'	(Dimensionless Henry's Law Constant, where H' = HLC x 41)	= chemical-specific, unitless
HLC	(Henry's Law Constant)	= chemical-specific, (atm-m^3/mol)
TAF	(Temperature adjustment factor)	= 0.5
$\theta_{w,cf}$	(Soil water-filled porosity in capillary fringe)	= 0.352 cm^3/cm^3
N	(Total soil porosity)	= 0.43 cm^3/cm^3

Soil Volatilization to Indoor Air Inhalation Criteria (SVIIC) Equations (R 299.24)

Equation for Carcinogens:

$$SVIIC = \frac{TR \times AT \; X \; AIR}{IURF \times EF \times ED \times CR_{building}}$$

where,

SVIIC	(Soil volatilization indoor air inhalation criterion)	= chemical-specific, ug/kg
TR	(Target risk level)	= 10^{-5}
AT	(Averaging time)	= 25,550 days (70 years x 365 days/year)
AIR	(Adjusted inhalation rate)	= 1 (residential) = 2 (nonresidential)
IURF	(Inhalation unit risk factor)	= chemical-specific, $(ug/m^3)^{-1}$
EF	(Exposure frequency)	= 350 days/year (residential) = 245 days/year (nonresidential)
ED	(Exposure duration)	= 30 years (residential) = 21 years (nonresidential)
$CR_{building}$	(Ratio of indoor air concentration to soil concentration)	= chemical-specific, $(ug/m^3)/(ug/kg)$

Equation for Non-carcinogens:

$$SVIIC = \frac{THQ \times AT}{(1/ITSL) \times EF \times ED \times CR_{building}}$$

where,

SVIIC	(Soil volatilization indoor air inhalation criterion)	= chemical-specific, ug/kg
THQ	(Target hazard quotient)	= 1
AT	(Averaging time)	= 10,950 days (residential) = 7,665 days (nonresidential)
EF	(Exposure frequency)	= 350 days/year (residential) = 245 days/year (nonresidential)
ED	(Exposure duration)	= 30 years (residential) = 21 years (nonresidential)
ITSL	(Initial threshold screening level)	= chemical-specific, ug/m^3
$CR_{building}$	(Ratio of indoor air concentration to soil concentration)	= chemical-specific, $(ug/m^3)/(ug/kg)$

$$CR_{building} = CR_{source}^{soil} \times \alpha$$

where,

$CR_{building}$	(Ratio of indoor air concentration to soil	= chemical-specific,

	concentration)	(ug/m^3)/(ug/kg)
α	(Attenuation coefficient)	= chemical-specific, Unitless
CR_{source}^{soil}	(Ratio of soil vapor concentration to soil/source concentration)	= chemical-specific, (ug/m^3)/(ug/kg)

$$CR_{source}^{soil} = \frac{H' \times TAF \times C_s \times \rho_b \times 10^{-3}\ kg/g \times 10^{6}\ cm^3/m^3}{\theta_w + (k_d \times \rho_b) + (H' \times TAF \times \theta_a)}$$

where,

CR_{source}^{soil}	(Ratio of soil vapor concentration to soil/source concentration)	= chemical-specific, (ug/m^3)/(ug/kg)
H'	(Dimensionless Henry's law constant, where H' = HLC x 41)	= chemical-specific, unitless
HLC	(Henry's law constant at 25 degrees Celsius)	= chemical-specific, (atm-m^3/mol)
TAF	(Temperature adjustment factor)	= 0.5, unitless
C_s	(Uniform concentration in soil)	= 1 ug/kg
ρ_b	(Dry soil bulk density)	= 1.5 g/cm^3
θ_w	(Soil water-filled porosity)	= 0.3 cm^3/cm^3
k_d	(Soil-water partition coefficient)	= chemical-specific, cm^3/g (equivalent to L/kg)
	For organic compounds	= K_{oc} (cm^3/g) x f_{oc} (g/g)
	For inorganic compounds	= chemical-specific, cm^3/g
K_{oc}	(Soil organic carbon partition coefficient)	= chemical-specific, cm^3/g
f_{oc}	(Fraction of organic carbon content of soil)	= 0.002 g/g (0.2%)
θ_a	(Soil air-filled porosity)	= 0.13 cm^3/cm^3

$$\alpha = \frac{\left[\left[\frac{D_v^{eff} A_b}{Q_{building} L_T}\right] \times \exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right)\right]}{\left[\exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) + \left[\frac{D_v^{eff} A_b}{Q_{building} L_T}\right] + \left[\frac{D_v^{eff} A_b}{Q_{soil} L_T}\right]\left[\exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) - 1\right]\right]}$$

where,

α	(Attenuation coefficient)	= unitless
D_v^{eff}	(Effective diffusion coefficient through vadose zone)	= chemical-specific, cm^2/s
D^{crack}	(Effective diffusion coefficient through crack)	= cm^2/s, ($D^{crack} = D_v^{eff}$, see equation for D_v^{eff} below)
A_b	(Area of enclosed space below grade)	= 1.96E+6 cm^2 (residential) = 3.83E+6 cm^2 (nonresidential)
$Q_{building}$	(Building ventilation rate)	= 1.51E+5 cm^3/s (residential) = 5.04E+5 cm^3/s (nonresidential)
L_{crack}	(Building foundation thickness)	= 15 cm
L_T	(Source-building separation distance)	= 15 cm (All land use categories)

Q_{soil}	(Volumetric flow rate of soil vapor into the building)	= 0.81 cm^3/s (residential) = 2.10 cm^3/s (nonresidential)
A_{crack}	(Total area of cracks below grade)	= 196 cm^2 (residential) = 383 cm^2 (nonresidential)
exp(p)	(The base of the natural logarithm raised to power p)	= e^p

$$D_v^{eff} = \left[D_a\left(\theta_a^{3.33} / n^2\right)\right] + \left[\frac{D_w}{H' \times TAF}\left(\theta_w^{3.33} / n^2\right)\right]$$

where,

D_v^{eff}	(Effective diffusion coefficient through vadose zone)	= chemical-specific, cm^2/s
D_a	(Diffusivity in air)	= chemical-specific, cm^2/s
θ_a	(Soil air-filled porosity)	= 0.13 cm^3/cm^3
n	(Total soil porosity)	= 0.43 cm^3/cm^3
D_w	(Diffusivity in water)	= chemical-specific, cm^2/s
H'	(Dimensionless Henry's law constant, where H' = HLC x 41)	= chemical-specific, unitless
HLC	(Henry's law constant	= chemical-specific, (atm-m^3/mol)
θ_w	(Soil water-filled porosity)	= 0.3 cm^3/cm^3

Appendix B:
Comparison of Assumptions for the Drinking Water Pathway

Parameter/ Variable	Michigan (2013)	EPA (Nov., 2013)	Indiana (2013)	Wisconsin (2013)	Minnesota (2008)	Ohio (2008)	Illinois (2013)
Information source(s)	Part 201 groundwater and soil cleanup criteria and screening levels	Regional Screening levels (RSLs) Introduction and Risk Assessment Guidance for Superfund (RAGS Part B)	Remediation Closure Guide with 2014 Screening Levels Tables Appendix A	WI Statute Chapter 160 groundwater law and NR140 public health or welfare related groundwater quality enforcement standard (ES)	2001 Health Standards Statute and Health Risk Limits Rules (Parts 4717.7810 through 4717.7900); Statement of Need and Reasonableness (SONAR)	Rule 3745-300-08 of the Administrative Code and Guidance and Support Document for the Development of Generic Numerical Standards	Part 742: Tiered approach to corrective action objectives; Part 620 Groundwater Quality
Link:	New Environmental Contamination Cleanup Criteria Rules effective 12/30/13 (1/24/2014)	• http://www.epa.gov/oswer/riskassessment/ragsb/index.htm; • http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm	• http://www.in.gov/idem/4153.htm	• https://docs.legis.wisconsin.gov/statutes/statutes/160.pdf; • https://docs.legis.wisconsin.gov/code/admin_code/nr/100/140.pdf; • http://dnr.wi.gov/topic/DrinkingWater/HealthAdvisoryLevels.html	• http://www.health.state.mn.us/divs/eh/risk/rules/water/index.html; • http://www.health.state.mn.us/divs/eh/risk/rules/water/hrlsonar08.pdf	• http://epa.ohio.gov/portals/30/vap/docs/support%20doc%20version.pdf	• http://www.ipcb.state.il.us/documents/dsweb/Get/Document-38408; • http://www.ipcb.state.il.us/documents/dsweb/Get/Document-33425; • http://www.ipcb.state.il.us/documents/dsweb/Get/Document-27419/
Residential							
Name of groundwater cleanup value:	Drinking water criteria	Tapwater RSL	Groundwater Screening Level	Public health or public welfare standards	Health Risk Limits (HRL) values and interim Health Based Values (HBV)	Unrestricted potable use groundwater standard	Tier 1 Groundwater Remediation Objectives for Class I and Class II groundwater
Drinking water intake rate for carcinogens with mutagenic mode of action (L/day)	—	ADAF and age adjusted using 4 age groups	Same as EPA	—	ADAF and age adjusted using 3 age groups	—	—

Parameter/ Variable	Michigan (2013)	EPA (Nov., 2013)	Indiana (2013)	Wisconsin (2013)	Minnesota (2008)	Ohio (2008)	Illinois (2013)
Drinking water intake rate for other carcinogens (CAs) (L/day)	—	Age adjusted for child and adult	Same as EPA	—	Time weighted average of the 95th percentile intake rate per body weight for acute and short-term, subchronic and chronic exposures.	1.3 (child) and 2 (adult)	2 (adult)
Drinking water intake rate for non-carcinogens (L/day)	2 (adult)	1 (child)	Same as EPA	1 (10 kg person)		1.3 (child)	2 (adult)
Drinking water intake rate - ages 1–6 yrs (L/day)	—	1 (child)	Same as EPA	—	1) 0.289 L/Kg-day (1–3 months) (Acute and short-term) 2) 0.077 L/Kg-day (birth–8 yrs) (Subchronic); Assuming BW = 15 kg, the intake rate would be 1.16 L/day 3) 0.043 L/Kg-day (> 8 yrs) (Chronic); Assuming BW = 70 kg, the intake rate would be 3 L/day.	1.3 (child)	—
Drinking water intake rate – ages 7–30 yrs (L/day) for carcinogens and non-carcinogens	2 (adult)	2	Same as EPA	—		Same as EPA	Same as EPA
Drinking water intake rate - ages < 2 yrs (L/day)	—	1	Same as EPA	—	0.137 L/Kg-day	—	—
Drinking water intake rate - ages 2–6 yrs (L/day)	—	1	Same as EPA	—	0.047 L/kg-day (2–16 yrs)	—	—
Drinking water intake rate - ages 6–16 yrs (L/day)	—	2	Same as EPA	—		—	—
Drinking water intake rate – ages 16–30 yrs (L/day)	—	2	Same as EPA	—	0.039 L/Kg-day	—	—

Parameter/ Variable	Michigan (2013)	EPA (Nov., 2013)	Indiana (2013)	Wisconsin (2013)	Minnesota (2008)	Ohio (2008)	Illinois (2013)
Relative source contribution for non-carcinogens	0.2 (20%)	1 (100%)	Same as EPA	Same as EPA	acute and short-term -0.5 (50%), subchronic and chronic - 0.2 (20%)	Same as EPA	Same as EPA
Cumulative effects of mixtures (more than one similar acting chemicals addressed?	No	Yes	Yes	Yes	Yes	Yes	Yes
Multiple pathways (ingestion, inhalation and dermal contact) aggregated?	No	Yes	Yes	No	No	Yes	No
Nonresidential							
Drinking water intake rate, nonresidential (worker) (L/day)	2 (adult)	NA	Same as EPA	Same as EPA	Risk managers have the option of applying HRLs to the general population, or adjusting them for subpopulations.	Same as EPA	1 (adult)
Relative source contribution for non-carcinogens	0.2 (20%)	NA	Same as EPA	Same as EPA		Same as EPA	1 (100%)

Appendix C:
Comparison of Assumptions for the Soils Pathway

Parameter/ Variable	Michigan	EPA	Indiana	Wisconsin	Minnesota	Ohio	Illinois
Information Source(s)	Part 201 groundwater and soil cleanup criteria and screening levels (2013)	Regional Screening levels (RSLs) Users Guide (Nov., 2013)	Remediation Closure Guide with 2014 Screening Levels Tables Appendix A (2013)	Chapter NR 720 Soil cleanup standards: Residual Contaminant Levels (RCL) (2013)	Soil Remediation Values (SRVs) Derivation, B.Brooks, MPCA, 2014)	Rule 3745-300-08 of the Administrative Code and Guidance and Support Document for the Development of Generic Numerical Standards (2008)	Part 742: Tiered approach to corrective action objectives (2013)
Source Web link	New Environmental Contamination Cleanup Criteria Rules effective 12/30/13 (1/24/2014)	• http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm	• http://www.in.gov/idem/4153.htm	• https://docs.legis.wisconsin.gov/code/admin_code/nr/700/720; • http://dnr.wi.gov/topic/Brownfields/professionals.html#tabx2; • http://dnr.wi.gov/files/PDF/pubs/rr/RR890.pdf	• Minnesota Pollution Control Agency Soil Reference Values Technical Support Document 2013. See Appendix G.	• http://epa.ohio.gov/derr/rules/guidance.aspx	• http://www.ipcb.state.il.us/documents/dsweb/Get/Document-38408
Residential Ingestion and Dermal Contact							
Ingestion Pathway							
Soil ingestion factor for carcinogens with mutagenic mode of action (mg-year/kg-day)	—	489.5	Same as EPA	NA	Calculated value not presented in source document	Calculated value not presented in source document	Calculated value not presented in source document
Soil ingestion factor for other carcinogens (CAs) (mg-year/kg-day)	114 (residential)	114	Same as EPA	Same as EPA	Calculated value not presented in source document	Calculated value not presented in source document	Calculated value not presented in source document

Parameter/ Variable	Michigan	EPA	Indiana	Wisconsin	Minnesota	Ohio	Illinois
Soil ingestion factor for non-carcinogens (mg-year/kg-day)	114 (residential) (age-adjusted)	80 (child receptor)	Same as EPA	Same as EPA	Calculated value not presented in source document	Calculated value not presented in source document	Calculated value not presented in source document
Soil ingestion rate - ages 1–6 yrs (mg/day)	200	200	Same as EPA	Same as EPA	—	Same as EPA	200
Soil ingestion rate – ages 7–30 yrs (mg/day)	100	100	Same as EPA	Same as EPA	—	Same as EPA	50
Soil ingestion rate - ages < 2 yrs (mg/day)	—	200	Same as EPA	Not known	Same as EPA	—	—
Soil ingestion rate - ages 2–6 yrs (mg/day)	—	200	Same as EPA	Not known	200 (ages 2–16 years)	—	—
Soil ingestion rate - ages 6–16 yrs (mg/day)	—	100	Same as EPA	Not known		—	—
Soil ingestion rate – ages 16–30 yrs (mg/day)	—	100	Same as EPA	Not known	Same as EPA	—	—
Dermal Contact Pathway							
Soil dermal factor for carcinogens with mutagenic mode of action (mg-year/kg-day)	—	1,445	Same as EPA	Same as EPA	Calculated value not presented in source document	Calculated value not presented in source document	Dermal contact exposure to soil is not evaluated under Tier 1
Soil dermal factor for other carcinogens (mg-year/kg-day)	353	361	Same as EPA	Same as EPA	Calculated value not presented in source document	Calculated value not presented in source document	
Soil dermal factor for non-carcinogens (mg-year/kg-day) (age adjusted for child and adult)	353	224 (child receptor)	Same as EPA	Same as EPA	Calculated value not presented in source document	Calculated value not presented in source document	

Parameter/ Variable	Michigan	EPA	Indiana	Wisconsin	Minnesota	Ohio	Illinois
Skin surface area - ages 1–6 yrs (cm2/event)	2,800	2,800	Same as EPA	Same as EPA	—	Same as EPA	
Skin surface area - ages 7–30 yrs (cm2/event)	5,800	5,700	Same as EPA	Same as EPA	—	Same as EPA	NA
Skin surface area - ages <2 yrs (cm2/event)	—	2,800	Same as EPA	Not known	2,600	—	NA
Skin surface area - ages 2–6 yrs (cm2/event)	—	2,800	Same as EPA	Not known	4,400 (2–16 yrs)	—	NA
Skin surface area - ages 6–16 yrs (cm2/event)	—	5,700	Same as EPA	Not known		—	NA
Skin surface area - ages 16–30 yrs (cm2/event)	—	5,700	Same as EPA	Not known	Same as EPA	—	NA
Soil adherence factor (AF) – 1–6 yrs (mg/cm2)	0.2	0.2	Same as EPA	Same as EPA	—	Same as EPA	NA
Soil adherence factor (AF) - ages 16–30 yrs (mg/cm2)	0.07	0.07	Same as EPA	Same as EPA	—	Same as EPA	NA
Soil adherence factor (AF) – ages <2 yrs (mg/cm2)	—	0.2	Same as EPA	Not known	Same as EPA	—	NA
Soil adherence factor (AF) - ages 2–6 yrs (mg/cm2)	—	0.2	Same as EPA	Not known	0.2 (2–16 yrs)	—	NA
Soil adherence factor (AF) - ages 6–16 yrs (mg/cm2)	—	0.07	Same as EPA	Not known		—	NA
Soil adherence factor (AF) - ages 16–30 yrs (mg/cm2), adult	—	0.07	Same as EPA	Not known	Same as EPA	—	NA

Parameter/ Variable	Michigan	EPA	Indiana	Wisconsin	Minnesota	Ohio	Illinois
Nonresidential Ingestion and Dermal Contact Pathways							
Soil ingestion rate, nonresidential (worker)	100	100 (outdoor or composite); 50 (indoor)	Same as EPA	Same as EPA (for outdoor and composite worker)	Same as EPA (for indoor worker)	Same as EPA (for indoor worker)	Same as EPA (for indoor worker)
Skin surface area, nonresidential (cm2/event)	5,700	3,300	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Dermal contact exposure to soil is not evaluated under Tier 1.
Soil adherence factor (AF), nonresidential/ worker (mg/cm^2)	0.07	0.2	Same as EPA	Same as EPA	Same as EPA	Same as EPA	
Residential and Nonresidential Ambient Air Inhalation							
Volatilization factor, chemical- and source area size-specific (m3/kg)	Chemical- and source area size-specific	Chemical- and source area size-specific	Chemical- and source area size-specific	Chemical- and source area size-specific	Chemical- and source area size-specific	Chemical- and source area size-specific	Chemical- and source area size-specific
Dispersion factor for 1/2 acre (source area size- and wind data-specific) (g/m2-s per kg/m3)	82.33 (Michigan data and ISC model)	68.81 (Regional data-specific and ISC model)	Same as EPA	Same as EPA	93.77	85.63	68.81 (residential); 85.81 (industrial/commercial)
Source area size or areal extent of the site of contamination (acre)	Site source area size	Site-specific	Site-specific	Site-specific	Site-specific	Site-specific	Site-specific
Normalized average flux from soil for residential or nonresidential (g/m2-s)	—	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific
Dry soil bulk density (g/m2-s)	1.5	1.5	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA

Parameter/ Variable	Michigan	EPA	Indiana	Wisconsin	Minnesota	Ohio	Illinois
Exposure time for averaging flux (3.15E+07 sec/year x ED or ED expressed in seconds)	9.45E+8 (ED=30 yrs); 6.62E+8 (ED=21 yrs)	1.89E+8 (ED=6 yrs); 7.9E+8 (ED=25 yrs)	Same as EPA	Same as EPA	9.45E+8 (ED=30 yrs)	9.50E+08 (ED=30 yrs); 7.88E+08 (ED=25 yrs)	9.50E+08 (ED=30 yrs); 7.9E+08 (ED=25 yrs)
Air-filled soil porosity (L_{air}/L_{soil}) (unitless)	0.28	0.28	Same as EPA	Same as EPA	0.28 (top 1 meter)	Same as EPA	Same as EPA
Water-filled soil porosity (L_{water}/L_{soil}) (unitless)	0.15	0.15	Same as EPA	Same as EPA	0.15 (top 1 meter)	Same as EPA	Same as EPA
Total soil porosity (L_{pore}/L_{soil})	0.43	0.43	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Organic carbon content of soil (g/g)	0.006	0.006	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Temperature adjustment factor (unitless)	0.5	None	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Particulate emission factor for 1/2 acre source (source size-specific) (m3/kg)	1.28E+08 (residential); 3.95E+07 (nonresidential) (Michigan data)	1.36E+09 (Minneapolis data)	Same as EPA	1.43E+09	1.38E+09 (residential); 6.8E+08 (commercial/industrial)	9.24 E+08 (Cleveland, OH data)	1.32E+09 (residential); 1.24E+09 (industrial/commercial) (Chicago data)
Dispersion factor for 1/2 acre source size (source area size-and wind speed-specific) (g/m2-s per kg/m3)	82.33	93.77 (based on Minneapolis wind data and ISC model)	68.81 (for ½ acre) (Regional data and ISC model)	98.43 (for ½ acre) (Chicago data and ISC model)	Same as EPA	85.63 (Cleveland, OH data)	90.80 (residential); 85.81 (industrial/commercial)
Emissions due to wind erosion, region-specific (Note: derivation and input values are not included in Rules) **(g/m2-sec)**	5.5E-7 (residential and nonresidential)	Ew value is not calculated	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA

Parameter/ Variable	Michigan	EPA	Indiana	Wisconsin	Minnesota	Ohio	Illinois
Michigan annual mean wind speed at measurement height (h) (m/sec)	4.56	4.69	Same as EPA	Same as EPA	Same as EPA	4.83	Same as EPA
Measurement height (h) (m)	6.4	Not known	Not known	Not known	Not known	Not known	Not known
Equivalent threshold friction value of wind speed at 7.0 m (m/sec)	9.51	11.32	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Function (F(x) derived using Cowherd et al. (1985) (unitless)	0.48	0.194	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Fraction of vegetative cover (unitless)	0.5	0.5	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Particulate emissions due to vehicle traffic (g/m2-sec)	3.7E-7 (residential); 1.8E-6 (nonresidential)	Not included in the generic calculation; recommended at sites with increased emissions due to traffic on unpaved contaminated roads.	Same as EPA	Same as EPA	Not included in PEF calculation.	Not included in PEF calculation.	Not included in PEF calculation.

Appendix D:
General Assumptions for all Pathways

Parameter/ Variable	Michigan	USEPA RSL	Indiana	Wisconsin	Minnesota	Ohio	Illinois
Information Source(s)	Part 201 groundwater and soil cleanup criteria and screening levels (2013)	Regional Screening levels (RSLs) Users Guide (Nov., 2013)	Remediation Closure Guide with 2014 Screening Levels Tables Appendix A (2013)	Chapter NR 720 Soil cleanup standards: Residual Contaminant Levels (RCL) (2013)	Soil Remediation Values (SRVs) Derivation, B.Brooks, MPCA, 2014)	Rule 3745-300-08 of the Administrative Code and Guidance and Support Document for the Development of Generic Numerical Standards (2009)	Part 742: Tiered approach to corrective action objectives (2013)
Information source link	• http://www.michigan.gov/deq/0,4561,7-135-3311_4109_4214-87388--,00.html	• http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm	• http://www.in.gov/idem/4153.htm; • http://www.in.gov/idem/files/risc_screening_table_2014_explanatory.pdf	• http://dnr.wi.gov/topic/Brownfields/professionals.html#tabx2; • http://docs.legis.wisconsin.gov/code/admin_code/nr/100/140.pdf	• Minnesota Pollution Control Agency Soil Reference Values Technical Support Document 2013. See Appendix G.	• http://epa.ohio.gov/derr/derrrules.aspx	• http://www.ipcb.state.il.us/documents/dsweb/Get/Document-38408
Target cancer risk (for *carcinogens*)	10^{-5}	10^{-6}	10^{-5}	10^{-5}	10^{-5}	10^{-5}	same as EPA
Hazard quotient (for *non-carcinogens*)	1	1	Same as EPA	Same as EPA	0.2	Same as EPA	Same as EPA
Averaging time for carcinogens (days) (365 days/year * lifespan)	25,550 (70 yr lifespan)	25,550 (70 yr lifespan)	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Residential-Specific							
Averaging time for *non-carcinogens* (days) (365 days/year x exposure duration, ED)	10,950 (ED=30 yrs)	2,190 (ED=6 yrs)	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA

Parameter/ Variable	Michigan	USEPA RSL	Indiana	Wisconsin	Minnesota	Ohio	Illinois
Exposure frequency (EF) for residential (days/year)	350	350	250 (soil pathway only)	Same as EPA	250; Same as EPA for non-VOCs ingestion route only	Same as EPA	Same as EPA
Exposure duration (ED) for *carcinogens (child and adult exposure)* (year)	30	30	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Exposure duration (ED) for *non-carcinogens* (year)	6 (child) and 24 (adult)	6 (child)	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Exposure duration - ages <2 years (year)	—	2	Same as EPA	Same as EPA	Same as EPA	—	—
Exposure duration - ages 2–6 years (year)	—	4	Same as EPA	Same as EPA	14 (ages 2–16 years)	—	—
Exposure duration - ages 6–16 years (year)	—	10	Same as EPA	Same as EPA		—	—
Exposure duration - ages 16–30 years (year)	—	14	Same as EPA	Same as EPA	Same as EPA	—	—
Exposure time (ET) at residence per 24-hour day (hours)	24	24	Same as EPA	Same as EPA	n/a	Same as EPA	Same as EPA
Body weight - ages <1–6 yrs	15	15	Same as EPA	15 (soil); 10 (groundwater)	—	Same as EPA	Same as EPA
Body weight - ages 6–30 yrs (kg)	70	70	Same as EPA	70 (soil); NA for groundwater	—	Same as EPA	Same as EPA
Body weight - ages < 2 yrs (kg)	—	15	Same as EPA	15 (soil); NA for groundwater	10	—	—
Body weight - ages 2–6 yrs (kg)	—	15	Same as EPA	15 (soil); NA for groundwater	36 (ages 2-16 years)	—	—
Body weight - ages 6–16 yrs (kg)	—	70	Same as EPA	70		—	—

Parameter/ Variable	Michigan	USEPA RSL	Indiana	Wisconsin	Minnesota	Ohio	Illinois
Body weight - ages 16–30 yrs (kg)	—	70	Same as EPA	70 (soil); NA for groundwater	Same as EPA	—	—
Cancer potency age-dependent adjustment factor for carcinogens with mutagenic mode of action (unitless)	—	10 for ages <2 yrs, 3 for ages 2–6 yrs and 6–16 yrs, and 1 for ages 16–30 yrs	Same as EPA	Same as EPA	Same as EPA	—	—
Nonresidential-specific							
Averaging time for *non-carcinogens* (365 days x ED)	7,665 (ED=21 yrs)	9,125 (ED=25 yrs) (soil); NA for groundwater	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Exposure duration (ED) (year)	21	25 (soil); NA for groundwater	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA
Exposure frequency (EF) (days/year)	245; 160 (dermal contact)	250 (soil); NA for groundwater	Same as EPA	Same as EPA	180; 250 for non-VOCs ingestion route	Same as EPA	250
Exposure time at work per 24-hour day (hours)	24	8 (soil); NA for groundwater	Same as EPA	Same as EPA	24	24	24
Body weight, nonresidential (kg)	70	70 (soil); NA for groundwater	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA

Appendix E:

EPA's Recommendations for New Default Exposure Factors

Attachment 1. Recommended Default Exposure Factors (2014)

Symbol	Definition (units)	Previous Default Value	Currently Recommended Value	Source of current recommendation	Source of previous recommendation
BW_a	Resident Body Weight - adult (kg)	70	80	U.S. EPA 2011a, Table 8-3; weighted mean values for adults 21 – 78	U.S. EPA 1991a (pg. 15)
Bw_w	Worker Body Weight (kg)	70	80	U.S. EPA 2011a, Table 8-3; weighted mean values for adults 21 – 78	U.S. EPA 1991a (pg. 15)
Exposure Frequency, Exposure Duration, and Exposure Time Variables					
EF_r	Resident Exposure Frequency (days/yr)	350	350	U.S. EPA 1991a (pg. 15); value not provided in EFH 2011	U.S. EPA 1991a (pg. 15)
EF_w	Worker Exposure Frequency (days/yr)	250	250	U.S. EPA 1991a (pg. 15); value not provided in EFH 2011	U.S. EPA 1991a (pg. 15)
EF_{iw}	Indoor Worker Exposure Frequency (days/yr)	250	250	U.S. EPA 1991a (pg. 15); value not provided in EFH 2011	U.S. EPA 1991a (pg. 15)
EF_{ow}	Outdoor Worker Exposure Frequency (days/yr)	225	225	U.S. EPA 1991a (pg. 15); value not provided in EFH 2011	U.S. EPA 1991a (pg. 15)
ED_r	Resident Exposure Duration (yr)	30	26	EPA 2011a, Table 16-108; 90th percentile for current residence time.	U.S. EPA 1991a (pg. 15)
ED_c	Resident Exposure Duration - child (yr)	6	6	U.S. EPA 1991a, Pages 6 and 15	U.S. EPA 1991a (pg. 15)
ED_a	Resident Exposure Duration - adult (yr)	24	20	EDr (26 years) - EDc (6 years)	U.S. EPA 1991a (pg. 15)
ED_w	Worker Exposure Duration - (yr)	25	25	U.S. EPA 1991a (pg. 15); EFH 2011 only provides a central tendency value	U.S. EPA 1991a (pg. 15)
ED_{iw}	Indoor Worker Exposure Duration (yr)	25	25	U.S. EPA 1991a (pg. 15); EFH 2011 only provides a central tendency value	U.S. EPA 1991a (pg. 15)
ED_{ow}	Outdoor Worker Exposure Duration (yr)	25	25	U.S. EPA 1991a (pg. 15); EFH 2011 only provides a central tendency value	U.S. EPA 1991a (pg. 15)
ET_{ra}	Resident Air Exposure Time (hours/day)	24	24	The whole day	The whole day
ET_{rs}	Resident Soil Exposure Time (hours/day)	24	24	The whole day	The whole day
ET_w	Worker Air Exposure Time (hr/hr)	8	8	The work day	The work day
ET_{ws}	Worker Soil Exposure Time (hours/day)	8	8	The work day	The work day
ET_{rw}	Resident Water Exposure Time (hours/day)	24	24	The whole day	The whole day
ET_{rwc}	Resident Water Exposure Time - child (hours/event)	1	0.54	U.S. EPA 2011a, Table 16-28; weighted average of 90th percentile time spent bathing (birth to <6 years)	U.S. EPA 2004
ET_{rwa}	Resident Water Exposure Time - adult (hours/event)	0.58	0.71	U.S. EPA 2011a, Tables 16-30 and 16-31; weighted average of adult (21 to 78) 90th percentile of time spent bathing/ showering In a day, divided by mean number of baths/showers taken in a day.	U.S. EPA 2004
Miscellaneous Variables; values not provided in EFH 2011					

Attachment 1. Recommended Default Exposure Factors (2014)

Symbol	Definition (units)	Previous Default Value	Currently Recommended Value	Source of current recommendation	Source of previous recommendation
Ingestion and Dermal Contact Rates					
IRW_c	Resident Drinking Water Ingestion Rate - Child (L/day)	1	0.78	U.S. EPA 2011a, Tables 3-15 and 3-33; weighted average of 90th percentile consumer-only ingestion of drinking water (birth to <6 years)	U.S. EPA 1989 (Exhibit 6-11)
IRW_a	Resident Drinking Water Ingestion Rate - Adult (L/day)	2	2.5	U.S. EPA 2011a, Table 3-33; 90th percentile of consumer-only ingestion of drinking water (≥ 21 years)	U.S. EPA 1989 (Exhibit 6-11)
IRS_c	Resident Soil Ingestion Rate - Child (mg/day)	200	200	U.S. EPA 2011a (Table 5-1); "upper-bound values" accounting for both soil and dust ingestion	U.S. EPA 1991a (pg. 15)
IRS_a	Resident Soil Ingestion Rate - Adult (mg/day)	100	100	U.S. EPA 1991a (pp. 6 and 15); EFH 2011 only provides a central tendency value	U.S. EPA 1991a (pg. 15)
IR_{iw}	Indoor Worker Soil Ingestion Rate (mg/day)	50	50	U.S. EPA 1991a (pp. 9-10, 15); EFH 2011 values not provided	U.S. EPA 1991a (pg. 15)
IR_{ow}	Outdoor Worker Soil Ingestion Rate (mg/day)	100	100	U.S. EPA 1991a (pg. 15), same as adult resident; EFH 2011 value not provided	U.S. EPA 1991a (pg. 15)
SA_c	Resident skin surface area - child (cm^2)	2,800	2,690	U.S. EPA 2011a, Tables 7-2 and 7-8; weighted average of mean values for head, hands, forearms, lower legs, and feet (male and female, birth to < 6 years)(forearm and lower leg-specific data used when available, ratios for nearest available age group used elsewhere (per EPA 2011b))	U.S. EPA 2002 (Exhibit 1-2)
SA_a	Resident skin surface area - adult (cm^2)	5,700	6,032	U.S. EPA 2011a, Tables 7-2 and 7-12; weighted average of mean values for head, hands, forearms, lower legs, and feet (male and female, 21+ years)(forearm and lower leg-specific data used for males and female lower leg; ratio of male forearm to arm applied to female arm data.	U.S. EPA 2002 (Exhibit 1-2)
SA_{ow}	Worker skin surface area - adult (cm^2)	3,300	3,470	US EPA 2011a, Table 7-2; weighted avergae of mean values for head, hands, and forearms (male and femalem, 21+years) (similar assumptions for forearms as used in EPA 2011b)	U.S. EPA 2002 (Exhibit 1-2)
SA_c	Resident Water Surface area - child (cm^2)	6,600	6,378	U.S. EPA 2011a, Table 7.10; weighted average of mean values for children <6 years.	U.S. EPA 2004 (Exhibit 3-2)
SA_a	Resident Water Surface area - adult (cm^2)	18,000	20,900	U.S. EPA 2011a, Table 7.10; weighted average of mean values for adults, male and female 21+.	U.S. EPA 2004 (Exhibit 3-2)
AF_c	Resident soil adherence factor - child (mg/cm^2)	0.2	0.2	U.S. EPA 2004 (Exhibit 3-5), RAGS Part E	U.S. EPA 2002 (Exhibit 1-2)
AF_a	Resident soil adherence factor - adult (mg/cm^2)	0.07	0.07	U.S. EPA 2004 (Exhibit 3-5), RAGS Part E	U.S. EPA 2002 (Exhibit 1-2)
AF_{ow}	Worker soil adherence factor - adult (mg/cm^2)	0.2	0.12	U.S. EPA 2011a, Table 7-20 and Section 7.2.2; arithmetic mean of weighted average of body part-specific (hands, forearms, and face) mean adherence factors for adult commercial/industrial activities	U.S. EPA 2002 (Exhibit 1-2)
BW_c	Resident Body Weight - child (kg)	15	15	U.S. EPA 2011a, Table 8-1; weighted average of mean body weights (birth to <6 years)	U.S. EPA 1991a (pg. 15)

Attachment 1. Recommended Default Exposure Factors (2014)

Symbol	Definition (units)	Previous Default Value	Currently Recommended Value	Source of current recommendation	Source of previous recommendation
AT_r	Averaging time - resident (days/year)	365	365	U.S. EPA 1989 (pg. 6-23)	U.S. EPA 1989 (pg. 6-23)
AT_w	Averaging time - composite worker (days/year)	365	365	U.S. EPA 1989 (pg. 6-23)	U.S. EPA 1989 (pg. 6-23)
AT_{iw}	Averaging time - indoor worker (days/year)	365	365	U.S. EPA 1989 (pg. 6-23)	U.S. EPA 1989 (pg. 6-23)
AT_{ow}	Averaging time - outdoor worker (days/year)	365	365	U.S. EPA 1989 (pg. 6-23)	U.S. EPA 1989 (pg. 6-23)
LT	Lifetime (years)	70	70	U.S. EPA 1989 (pg. 6-22), pending additional input from NCEA	U.S. EPA 1989 (pg. 6-22)
IR_{fish}	Fish Ingestion Rate (mg/day)	5.4×10^4	**	Recommend using site-specific values	U.S. EPA 1991a (pg. 15)
$IR_{produce}$	Consumption of homegrown produce (g/day)	42 (fruit); 80 (veg)	**	Recommend using site-specific values	U.S. EPA 1990

References for Cited Sources:

U.S. EPA 1989. Risk assessment guidance for Superfund. Volume I: Human health evaluation manual (Part A). Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89/002.

U.S. EPA 1990. Exposure Factors Handbook. Office of Health and Environmental Assessment. EPA / 8-89 / 043, March 1990.

U.S. EPA 1991a. Human health evaluation manual, supplemental guidance: "Standard default exposure factors". OSWER Directive 9285.6-03.

U.S. EPA 1991b. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals). Office of Emergency and Remedial

U.S. EPA. 1996a. Soil Screening Guidance: User's Guide. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-

U.S. EPA. 1996b. Soil Screening Guidance: Technical Background Document. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-

U.S. EPA. 1997a. Exposure Factors Handbook. Office of Research and Development, Washington, DC. EPA/600/P-95/002Fa.

U.S. EPA 2000. Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds. Part I: Estimating Exposure to Dioxin-Like Compounds. Volume 3--

U.S. EPA, 2001. WATER9. Version 1.0.0. Office of Air Quality Planning and Standards, Research Triangle Park, NC.

U.S. EPA 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24. December 2002.http://www.epa.gov/superfund/health/conmedia/soil/index.htm

U.S. EPA 2004. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. OSWER 9285.7-02EP.July

U.S. EPA, 2005. Guidance on Selecting Age Groupsfor Monitoring and Assessing Childhood Exposures to Environmental Contaminants. EPA/630/P-03/003F, November, 2005.

U.S. EPA 2009. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment) Final. OSWER 9285.7-82.2009.

U.S. EPA 2011a. Exposure Factors Handbook: 2011 Edition. EPA/ 600/ R-090/052F. September 2011.

EPA. 2011b. "Regional Screening Levels (Formerly PRGs), User's Guide." November. On-Line Address: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

Footnote: Users are directed to the *Exposure Factors Handbook* (2011) as a source for specific age-group exposure factors as described in EPA, 2005.

Appendix F:

Comparison of Drinking Water Criteria for the EPA and Region 5 States

Information (March, 2014)	**Michigan Department of Environmental Quality**	**US Environmental Protection Agency**	**Indiana Department of Environmental Management**	**Wisconsin Department of Health Services and Department of Natural Resources**	**Minnesota Department of Health**	**Ohio Environmental Protection Agency**	**Illinois Environmental Protection Agency**
Information source(s)	Part 201 groundwater and soil cleanup criteria and screening levels (2013)	Regional Screening levels (RSLs) Introduction and Risk Assessment Guidance for Superfund (RAGS Part B) (Nov. 2013 update)	Remediation Closure Guide with 2014 Screening Levels Tables Appendix A (2013)	WI Statute Chapter 160 groundwater law, NR140 public health or welfare related groundwater quality enforcement standard (ES) (1984-2007)	2001 Health Standards Statute and Health Risk Limits Rules (Parts 4717.7810 through 4717.7900) (2007-2013)	Rule 3745-300-08 of the Administrative Code and Guidance and Support Document for the Development of Generic Numerical Standards (2009)	Part 742: Tiered approach to corrective action objectives; Part 620 Groundwater Quality (amended 2013)
Source Web link	New Environmental Contamination Cleanup Criteria Rules effective 12/30/13 (1/24/2014)	• http://www.epa.gov/oswer/riskassessment/ragsb/index.htm; • http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm	• http://www.in.gov/idem/4153.htm	• https://docs.legis.wisconsin.gov/statutes/statutes/160.pdf; • https://docs.legis.wisconsin.gov/code/admin_code/nr/100/140.pdf; • http://dnr.wi.gov/topic/DrinkingWater/HealthAdvisoryLevels.html	• http://www.health.state.mn.us/divs/eh/risk/rules/water/index.html	• http://epa.ohio.gov/derr/rules/guidance.aspx	• http://www.ipcb.state.il.us/documents/dsweb/Get/Document-38408; • http://www.epa.state.il.us/land/taco • http://www.ipcb.state.il.us/documents/dsweb/Get/Document-33425; • http://www.ipcb.state.il.us/documents/dsweb/Get/Document-27419/
Update schedule	Not known	Semiannually	Annually (with 6 months transition period)	By petition or as necessary	MDH rulemaking was authorized under the 1989 Groundwater Protection Act and rules were promulgated in 1993, 1994, 2007, 2009, 2011, and 2013.	5 years (effective date 2009; review date 2014)	Not known

Information (March, 2014)	**Michigan Department of Environmental Quality**	**US Environmental Protection Agency**	**Indiana Department of Environmental Management**	**Wisconsin Department of Health Services and Department of Natural Resources**	**Minnesota Department of Health**	**Ohio Environmental Protection Agency**	**Illinois Environmental Protection Agency**
Name of default/generic cleanup values	Drinking water criteria	Tapwater Regional Screening Levels (RSL)	Groundwater Screening Levels (based on EPA RSL with modification)	Public health or public welfare standards	Health Risk Limits (HRL) Values and interim Health Based Values (HBV)	Unrestricted potable use groundwater standard	Tier 1 Groundwater Remediation Objectives (GRO) for Class I (potable resource) and Class II (general resource) groundwater
Purpose of cleanup values	Cleanup criteria to evaluate sites and determine if site is a "facility"	Recommended screening values to screen sites that may require groundwater cleanup or further investigation	Recommended screening values	Enforceable standards	Enforceable standards	Mandatory standards	mandatory cleanup standards to determine sites that may require Tier 2 or Tier 3 evaluation
Determination of final cleanup value	Uses the state drinking water standards (e.g. MCLs) as the default DWC. For chemicals without state standards, risk-based criteria is calculated for the ingestion pathway.	Uses the Safe Drinking Water Act maximum contaminant levels (MCLs) as the default residential tapwater RSL. For chemicals without MCLs, the screening levels are the calculated risk-based tapwater RSL	Uses the MCL as the residential ground water screening level. For chemicals without MCLs, the screening levels are the tapwater RSL modified to meet a cancer risk of 10^{-5}	Dept. of Health Services (DHS) under Ch. 160 statute develops the groundwater enforceable standards (ES) for DNR. DNR NR 140 presents these health and welfare based ESs. The ESs are based on EPA numbers (MCL) when available. These are used as guidance for water consumption advisories and groundwater remediation decisions.	Chapter 147, Article 17, section 2) declared HRLs for all contaminants in private domestic wells to be the more stringent of either the state standards or the federal MCLs. In absence of federal standard, state health-based values are used for private drinking water sources and remediation programs.	Tables V or VI of rule 3745-300-08 List of standards are based on maximum contaminant levels or other state-based criteria including risk-derived groundwater standards.	Groundwater remediation objectives (GRO) for the groundwater component of the groundwater ingestion exposure route are based on groundwater quality standards developed under Part 620. Primary drinking standards generally use USEPA MCLs (Part 611). GRO values are further corrected for cumulative effect of mixtures of similar-acting non-cancer chemicals.
Risk-based Cleanup Value Application:							
Land use	Residential and nonresidential	Residential	Same as EPA	Apply to all land uses	Apply to all land uses	Residential, commercial, industrial and construction or excavation worker	Apply to all land uses

Information (March, 2014)	**Michigan Department of Environmental Quality**	**US Environmental Protection Agency**	**Indiana Department of Environmental Management**	**Wisconsin Department of Health Services and Department of Natural Resources**	**Minnesota Department of Health**	**Ohio Environmental Protection Agency**	**Illinois Environmental Protection Agency**
Pathway(s) included	Ingestion	Combined ingestion, dermal contact and inhalation	Same as EPA	Ingestion	Ingestion	Combined ingestion, dermal and inhalation; assumes that the ground water will be used as a source of water for drinking, cooking, showering and bathing.	Ingestion
Toxicity basis	Cancer and non-cancer	Cancer, mutagenic cancer and non-cancer	Same as EPA	Cancer and non-cancer	Mutagenic cancer, cancer non-cancer values.	Cancer and non-cancer	Cancer and non-cancer
Receptors:							
Residential carcinogens	Adult (30 year exposure)	Child and adult (age-adjusted 30 year exposure)	Same as EPA	Child (10 kg person)	Same as EPA	Same as EPA	—
Residential non-carcinogens	Adult (30 year exposure)	0-6 yr old children (default for residential); adult (for residential where only adults are exposed, e.g. Prisons and senior retirement homes)	Same as EPA, but no residential adult	Child (10 kg person)	Non-cancer hrls for acute/short term (0-3 months), subchronic (up to 8 yrs) and chronic values (child and adult) are derived. Non-chronic values for non-cancer effects protect for subpopulations.	Same as EPA but no residential adult	Adult
Nonresidential	Adult (21 year exposure)	None (residential tapwater RSLis applied to other land uses)	Same as EPA	Same as EPA	Same as EPA	Same as EPA	—

Appendix G:

Comparison of Soil Contact Criteria for the EPA and Region 5 States

Information (as of March, 2014)	Michigan Department of Environmental Quality	US Environmental Protection Agency	Indiana Department of Environmental Management	Wisconsin Department of Natural Resources	Minnesota Pollution Control Agency (in process)	Ohio Environmental Protection Agency	Illinois Environmental Protection Agency
Information Source(s)	Part 201 groundwater and soil cleanup criteria and screening levels (December, 2013)	Regional Screening levels (RSLs) Users Guide (Nov. 2013 update)	Remediation Closure Guide with 2014 Screening Levels Tables Appendix A (2013-2014)	Chapter NR 720 Soil cleanup standards: Residual Contaminant Levels (RCL) (2013 amendment)	Soil Remediation Values (SRVs) Derivation, B.Brooks, MPCA, 2014)	Rule 3745-300-08 of the Administrative Code and Guidance and Support Document for the Development of Generic Numerical Standards (2009)	Part 742: Tiered approach to corrective action objectives (amended 2013)
Source Web link	New Environmental Contamination Cleanup Criteria Rules effective 12/30/13 (1/24/2014)	http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm	http://www.in.gov/idem/4153.htm	http://dnr.wi.gov/topic/Brownfields/documents/regs/NR700rules.pdf	http://www.pca.state.mn.us/index.php?option=com_k2&view=item&layout=item&id=4305#remediation-division-guidance-and-policy-slv,-cad-guidance-policy	http://epa.ohio.gov/derr/rules/guidance.aspx	http://www.ipcb.state.il.us/documents/dsweb/Get/Document-38408
Update schedule	2002 Rules were updated in 2013	Semiannually	Annually (with 6 months transition period)	EPA RSL calculator and Wisconsin-default exposure assumptions are used to derive the RCL. Wisconsin generally follows EPA changes to the default exposure assumptions.	The 1998 SRV guidance has been updated. The entries in this table are information from MPCA staff; updated guidance is expected to be finalized this year.	2009 Rules: Ohio EPA Voluntary Action Program concerning Generic Numerical Standards (Rule 3745-300-08) and Property-Specific Risk Assessment Procedures (Rule 3745-300-09)	2007 Rules amended on 2013

Information (as of March, 2014)	Michigan Department of Environmental Quality	US Environmental Protection Agency	Indiana Department of Environmental Management	Wisconsin Department of Natural Resources	Minnesota Pollution Control Agency (in process)	Ohio Environmental Protection Agency	Illinois Environmental Protection Agency
Name of default/generic cleanup values	Generic soil cleanup criteria and screening levels	Default Regional Screening Levels (RSL)	Direct Contact Screening Levels (based on EPA RSL with modification)	Residual Contaminant Level based on protection of human health from direct contact with contaminated soil	Soil Remediation Values (SRV)	Direct Contact Soil Standards	Tier 1 Soil Remediation Objectives (SRO)
Purpose of cleanup values	Cleanup criteria to evaluate sites and determine if site is a "facility"	Recommended screening values to screen sites that may require cleanup or further investigation	Recommended screening values	Mandatory standards	Guidance values	Mandatory standards	Mandatory cleanup standards to determine sites that may require Tier 2 or Tier 3 evaluation
Site-specific or tier 2 cleanup values and purpose	Site-specific criteria available for use at sites where generic assumptions don't apply or can be used as an option for further evaluation of a site determined to be a "facility"	Site-specific SL recommended for sites where RSL assumptions do not apply or as a tool for evaluating sites with RSL exceedances	Site-specific SL recommended for sites where RSL assumptions do not apply or as a tool for evaluating sites with RSL exceedances	Site-specific RCL or performance standards are options	Higher tier values used for evaluating sites with SRV exceedances	Property-specific risk values used for evaluating sites with numerical standards exceedances	Tier 2 or Tier 3 Soil Remediation Objective (SRO) required to evaluate sites with Tier 1 exceedances
Soil cleanup values types:							
	Direct Contact Criteria (DCC) (sum of ingestion and dermal contact pathways)	Total Soil RSL (combined pathways: ingestion, dermal contact and inhalation)	Direct Contact Screening Level (combined pathways: ingestion, dermal contact, and inhalation of volatiles and particulates)	Residual Contaminant Level (combined pathways: ingestion, dermal contact, and inhalation of volatiles and particulates)	Soil Remediation Value (combined pathways: ingestion, dermal contact, and inhalation of volatiles and particulates)	Direct Contact Soil Standard (combined pathways: ingestion, dermal contact, and inhalation of volatiles and particulates)	Tier 1 SRO for ingestion pathway only (dermal contact is considered under Tier 2 and 3)

Information (as of March, 2014)	Michigan Department of Environmental Quality	US Environmental Protection Agency	Indiana Department of Environmental Management	Wisconsin Department of Natural Resources	Minnesota Pollution Control Agency (in process)	Ohio Environmental Protection Agency	Illinois Environmental Protection Agency
	Soil Criteria for inhalation of volatiles (VSIC) and particulates (PSIC)	The inhalation pathway for volatiles and particulates are combined; Final RSL combines inhalation, ingestion and dermal SLs	Same as EPA	Same as EPA	Same as EPA	Same as EPA	SRO for outdoor inhalation pathway
	Soil criteria for the protection of groundwater as drinking water	Soil SL protective of groundwater	Residential migration to groundwater	RCL based on protection of groundwater	Soil Leaching Values (May, 2013)	Leach based soil values/soil standards for leaching	SRO for the soil component of the groundwater ingestion route
Cleanup value application:							
Land use	Residential and nonresidential (worker)	Residential child, residential adult, industrial (indoor, outdoor or composite worker), construction and recreational	Residential, commercial/industrial, and excavation worker	Non-industrial and industrial	Residential/ recreational and commercial/ industrial	Residential, commercial, industrial and construction or excavation worker	Residential and industrial/ commercial or construction worker
Soil Pathways	Ingestion, dermal contact and ambient air inhalation	Ingestion, dermal contact and inhalation	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Ingestion and outdoor inhalation
Toxicity basis	Cancer and noncancer	Cancer, mutagenic cancer and noncancer	Same as EPA	Same as EPA	Same as EPA	Cancer and noncancer	Cancer and noncancer
Receptors							
Residential carcinogens	Child and adult (age-adjusted 30 year exposure)	Child and adult (age-adjusted 30 year exposure)	Same as EPA	Same as EPA	Same as EPA	Same as EPA	Same as EPA

Information (as of March, 2014)	Michigan Department of Environmental Quality	US Environmental Protection Agency	Indiana Department of Environmental Management	Wisconsin Department of Natural Resources	Minnesota Pollution Control Agency (in process)	Ohio Environmental Protection Agency	Illinois Environmental Protection Agency
Residential non-carcinogens	Child and adult (age-adjusted 30 year exposure)	0–6 yr old children (default for residential); adult (for residential where only adults are exposed, e.g. prisons and retirement homes)	Same as EPA but no residential adult	Same as EPA but no non-industrial adult	Same as EPA but no residential adult	Same as EPA but no residential adult	Same as EPA for ingestion; child and adult for inhalation
Nonresidential	Nonresidential (worker)	Indoor, outdoor, or composite workers (25 yr exposure) and construction workers (1 year exposure)	Commercial/industrial and excavation worker	Industrial (worker)	Commercial/industrial worker	Commercial, industrial and construction or excavation worker	Industrial/commercial and construction worker